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Analysis of Weekday/Weekend Differences in Ambient Air Quality and Meteorology in the South Coast Air Basin

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

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Research Division

ANALYSIS OF WEEKDAY/WEEKEND DIFFERENCES IN AMBIENT AIR QUALITY AND METEOROLOGY IN THE SOUTH COAST AIR BASIN

Final Report
Contract No. 95-334

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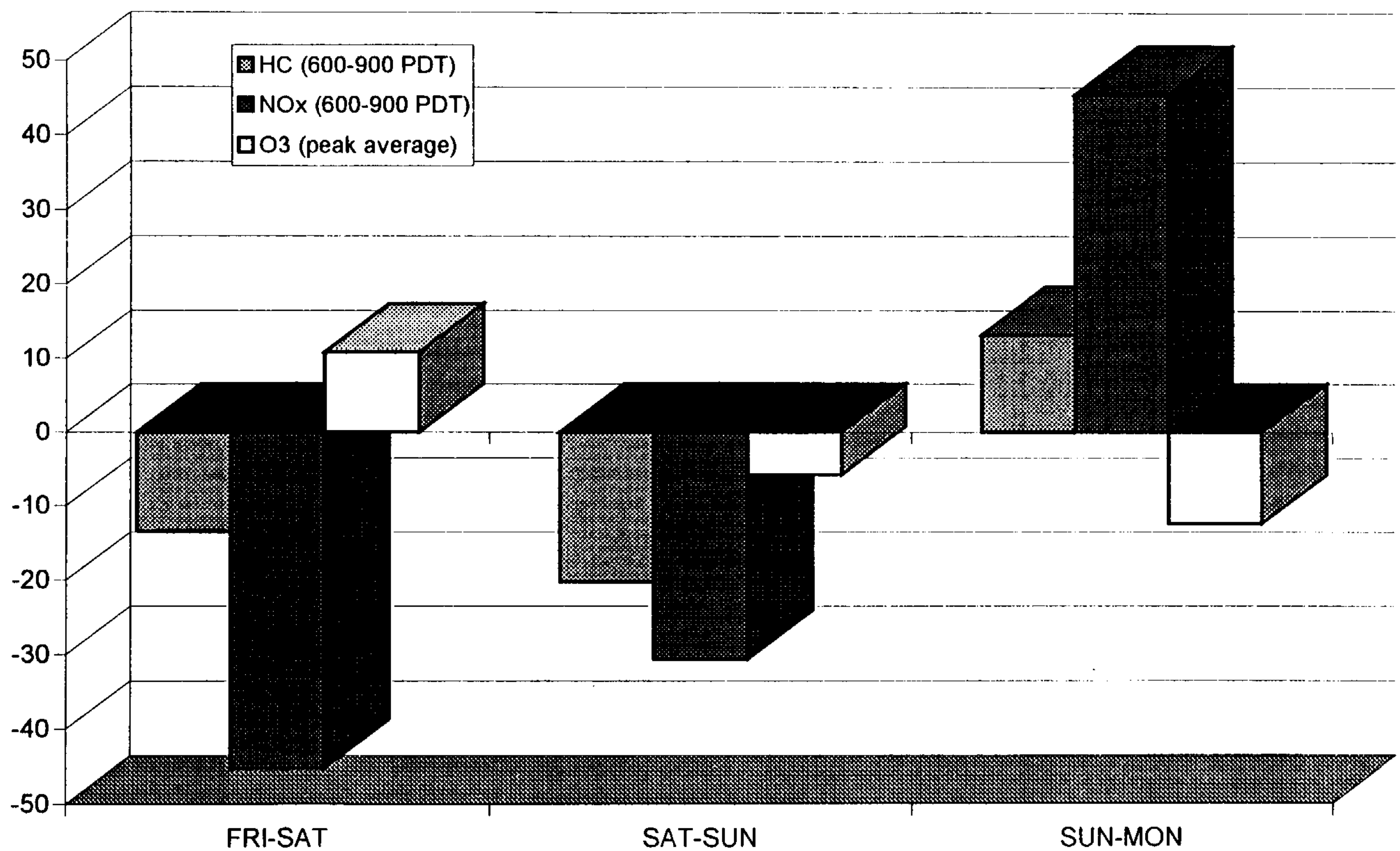
PERCENT CHANGES FOR O3, VOC, AND NOX FOR 1994-1995 SMOG SEASONS



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ABSTRACT

Airshed modeling undertaken for evaluation of various emission control strategies has typically utilized only a few air pollution episodes, which may or may not represent either the typical meteorological conditions associated with high ozone episodes, or the possible impact of day-of-the-week variation in precursor emissions or meteorological conditions. The present research effort focused on California's South Coast Air Basin (SoCAB) "smog season" of 1 May to 31 October for the years 1986-96, and had the following primary objectives: to expand the meteorological and ambient air quality databases developed in the previously reported-on first phase of this project; to further examine the degree of correlation between ozone and NO_2 and NO_x ambient air concentrations and implications for day-of-the-week variation in carry-over; and to perform the first-ever investigation, for the SoCAB, of possible day-of-the-week variation in meteorological conditions due to anthropogenic influences. In addition, a number of related exploratory studies were conducted, including analysis of the monthly and day-of-the-week distributions of high and middle ozone days, use of gridded meteorological data to objectively determine large-scale meteorological conditions associated with high ozone episodes, and examination of the potential utility of available data for industrial emissions and traffic activity patterns.

Results suggest that precursor carryover from Friday evening to Saturday may be of greater significance than that occurring during the middle-of-the-week but that carryover effects for NO_2 and NO_x are modest at best throughout the week. Examination of 1986-96 data yielded general confirmation of the findings in the Phase I study that morning NO_2 correlates best with the ozone maximum in the same subregion, and that Coastal/Metropolitan NO_2 no longer correlates well with the afternoon Basin ozone maximum.

Analysis of the day-of-the-week variations in ambient concentrations of NMHC, NO_x, and peak ozone for the recent 1994-95 period suggests that reductions in ozone precursor concentrations from Friday to Saturday and from Saturday to Sunday coincide with increases in weekend Basin peak ozone levels relative to Friday. However, examination of trends over the eleven-year period 1986-96 indicates that ozone levels in the SoCAB have decreased substantially, coinciding with decreases in both NO_x and NMHC ambient concentrations. Thus the transitory "weekend effect" we and others have identified does not provide evidence that further NO_x reductions for all days of the week will produce a corresponding increase in ambient ozone concentrations.

A general decrease in morning NO_2, NO_x, and NMHC ambient concentrations was found to have occurred over the eleven-year study period, along with a general decrease in hours and days of ozone exceedance at all concentration levels, and more notably in the number of hours of high concentrations. A more dramatic decrease in Basinwide

concentrations of both NO_x and NMHC (~20-25%) occurred between summer (July through September) 1995 and summer 1996. This appears to be a consequence of the introduction of RFG Phase II gasoline. Although a commensurate substantial reduction was seen in certain ozone metrics for mid-Basin stations, the overall magnitude of corresponding reduction in ozone concentrations was perhaps less dramatic, except for the decrease in first stage ozone alerts from 7 to 1.

Investigation of anthropogenic influences on day-of-the-week variations in SoCAB meteorological conditions yielded only one weak positive result: a general tendency for weekday surface air temperatures to be slightly warmer than corresponding weekend temperatures. The very small magnitude of the difference suggests this finding is unlikely to be of consequence to air quality management efforts. A gradual increase between 1949 and 1994 in the mean smog season daily-maximum temperature of about 2 °F was observed, however, for both weekdays and weekend days at the Los Angeles Civic Center.

Exploratory analyses of the respective distributions through the smog season of groups of days with high and average SoCAB peak hourly-average ozone concentrations indicates that highest ozone days tended to occur mostly during the middle of the smog season while middle ozone days were more broadly distributed. Highest ozone days also tended to occur more often late rather than early in the week (i.e., Friday, Saturday rather than Sunday, Monday).

Exploratory analyses using gridded meteorological data to objectively determine the large-scale meteorological conditions associated with high ozone episodes showed these events tended to be associated with a strong 500 mb west coast ridge and offshore trough, with these features shifting slightly eastward during the 36-hour period leading up to the occurrence of the composite high ozone event. High correlations were found between SoCAB maximum ozone concentration and objectively-analyzed same-day 1700 PDT 850 mb temperatures.

Implications of these results for NO_x and VOC control strategies will remain unclear until more accurate emissions data (especially for speciated VOC) become available for the SoCAB by day-of-the-week and by subregion, and until a more robust quantitative relationship is developed between key ozone metrics and ambient meteorological conditions. Improved understanding of the detailed three-dimensional airflow through the SoCAB, and its diurnal variation during specific air pollution episodes, would also be extremely helpful in this regard.

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DISCLAIMER

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GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

AIRS	Aerometric Information Retrieval System
AQMD	South Coast Air Quality Management District
AQMP	Air Quality Management Plan
ARB	California Air Resources Board
BAM	Beta Attenuation Monitor
B_{scat}	scattering coefficient
CD-ROM	Computer Disk-Read Only Memory
CDF	California Department of Forestry
CIMIS	California Irrigation Management and Information Systems
CMAN	Coastal-Marine Automated Network
CO	carbon monoxide
CO/MET	Coastal/Metropolitan
DRI	Desert Research Institute
EPA	US Environmental Protection Agency
FAA	Federal Aviation Administration
GEMPACK	General Meteorological Package
GMT	Greenwich Mean Time
HC	hydrocarbons
HCHO	formaldehyde
INV	Inland Valley
LAX	Los Angeles International Airport
MM5	NCAR Mesoscale Model Version 5
MTBE	Methyl-tertiary butyl ether
NAAQS	National Ambient Air Quality Standards
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDIR	nondispersive infrared
NGM	Nested Grid Model
NMHC	Non-methane hydrocarbon
NOAA	National Oceanic and Atmospheric Administration
NO	nitric oxide

NO_2	nitrogen dioxide
NO_x	nitrogen oxides
O_3	ozone
PAMS	Photochemical Assessment Monitoring Stations
PDT	Pacific Daylight Time
PM_{10}	particulate matter less than 10 μm in diameter
PST	Pacific Standard Time
RASS	Radio Acoustic Sounding System
RAWS	Remote Automated Weather Service
RECLAIM	Regional Clean Air Incentives Market
RFG	Reformulated Gasoline
RWP	Radar Wind Profiler
SCAQMD	South Coast Air Quality Management District
SCAQS	Southern California Air Quality Study
SCE	Southern California Edison
SCOS97	1997 Southern California Ozone Study
SGV	San Gabriel Valley
SIC	Source Industrial Code
SoCAB	South Coast Air Basin
So_x	oxides of sulfur
TEOM	Tapered Element Oscillating Microbalance
THC	total hydrocarbon
TPD	tons per day
TSP	total suspended particles
UAM	Urban Airshed Model
UCLA	University of California, Los Angeles
UV	ultraviolet region
VMT	vehicle miles traveled
VOC	volatile organic compound
WD	weekday
WE	weekend
WWW	World Wide Web

1.0 EXECUTIVE SUMMARY

1.1 Introduction

The air quality in the California South Coast Air Basin (SoCAB) has improved over the past two decades as a direct result of strategic ROG and NO_x control programs mandated and implemented by the California Air Resources Board (ARB) and by the South Coast Air Quality Management District (SCAQMD). Empirical evidence from long-term trend data, for both emission inventories and ambient air quality, suggests that reduction in oxides of nitrogen has been beneficial in reducing peak levels of ozone in the SoCAB. In addition, photolysis of nitrogen dioxide remains the only significant pathway to ozone formation in the troposphere.

Nonetheless, some Urban Airshed Modeling (UAM) results predict that NO_x control beyond the residual 500 tons per day (TPD) estimated to be needed to meet the National Ambient Air Quality Standard (NAAQS) for PM-10 (or PM-2.5), will lead to increasing ozone in the SoCAB (AQMP Task Force 1994). Most of the regional modeling thus far undertaken for the SoCAB, however, has been conducted for only a few pollution episodes, and thus may not represent high ozone episode conditions over a sufficiently wide range of meteorological conditions. Additionally, reliance upon such a small number of episodes has precluded proper consideration of the distinction between weekday and weekend episodes. Clearly, then, there is a need to consider whether there may be systematic variations in meteorological conditions and pollutant carryover by day-of-the-week.

1.2 Objectives

The primary overall objectives of this project were: (1) to examine weekday/weekend differences in ambient air quality, and their implications for carryover and other effects; and (2) to investigate weekday/weekend differences in SoCAB meteorological conditions (if any) resulting from anthropogenic influences.

The specific objectives of the project were:

- To expand our previous meteorological and ambient air quality databases, developed under ARB support, through inclusion of additional years of data and additional meteorological data and pollutants.
- Using this database, to further characterize recent (*i.e.*, past decade) correlations (or lack thereof) between ozone and previous evening or same day morning NO_2 and NO_x ambient air concentrations. In particular, to further investigate differences in ambient air quality between weekdays and weekend days as a means of identifying whether carryover[1] and/or differences in emissions as a function of day-of-the-week are critical to observed air quality patterns.
- To investigate, for the first time for the SoCAB, whether anthropogenic influences, for example heat island effects and vehicle use patterns (and their resulting particulate emissions), cause differences between SoCAB micrometeorology on weekend days vs. weekdays.
- (Exploratory) To examine the relationship between high ozone episodes in the SoCAB and both concurrent and antecedent meteorological conditions, using synoptic-scale gridded fields of meteorological parameters.

1.3 Expansion of Phase I Databases

Additional surface meteorological data sets have now been acquired and archived. Meteorological data sets for 1994-96 and surface pressure gradient data for 1986-95 were acquired from the SCAQMD. Surface airways data for 1991-96 were obtainable from the computer archives of the UCLA Department of Atmospheric Sciences, while we obtained 1993-96 data for the Remote Automated Weather Stations (RAWS) in the region of the SoCAB from the California Department of Forestry (CDF). Local offshore meteorological buoy data for 1986-96 were also acquired.

Meteorological data for an additional nine sites in Southern California were obtained from the meteorological network maintained by Southern California Edison (SCE). Locations of these sites and other surface meteorological sites in the SoCAB are

[1] Nitrogen oxides have shorter lifetimes than hydrocarbons and ozone & carryover over time periods longer than 8 hours involves mostly ozone and hydrocarbons.

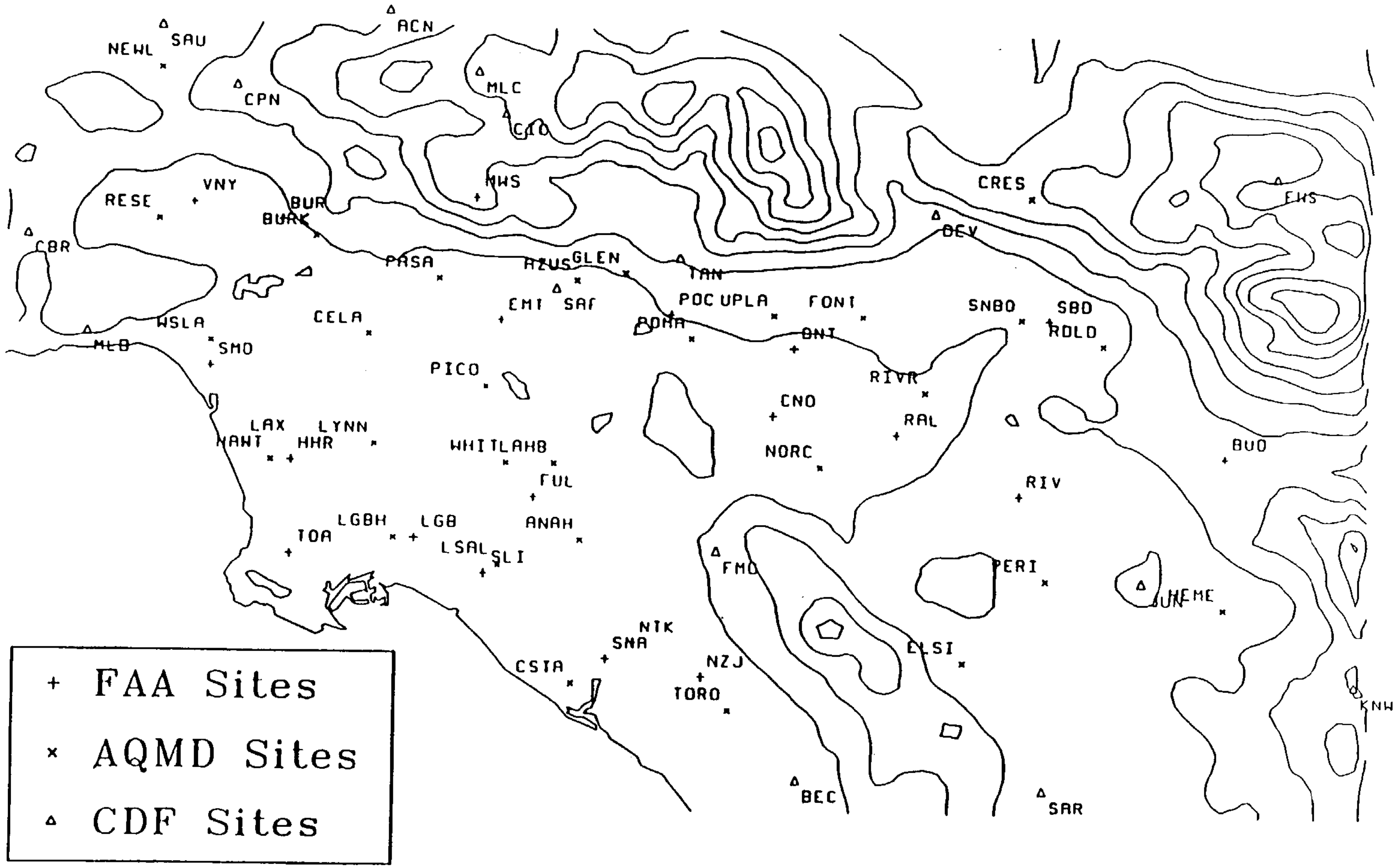

Figure 1-1. Surface meteorological sites in the South Coast Basin. Thin solid lines indicate surface elevation at 1000 ft increments.

shown in Figure 1-1. In addition, substantial meteorological data were obtained from the ARB for many observing sites in or near the SoCAB.

A significant new addition to our meteorological data archive was the Los Angeles International Airport profiler data for wind and temperature received from the SCAQMD for the period June 1994 to February 1997. Other newly acquired upper air data sets included California sounding data for 1990-96, vertical profiler data (for about 25 days total) from the Southern California Air Quality Study, and soundings from Claremont during the period 2-20 September 1993. We also acquired Radar Wind Profiler and Radio Acoustic Sounding System (RWP-RASS) bird-filtered data from the ARB for several sites in Southern California for various periods of time during 1992.

Climatological daily-maximum and daily-minimum temperatures were acquired for May-October 1986-96 for four sites: Los Angeles International Airport, Los Angeles Civic Center, San Gabriel Fire Department, and San Bernardino County Hospital. For the Los Angeles Civic Center site, daily-maximum and daily-minimum temperatures were also acquired for each day of the year in the period 1949-94.

As an exploratory task in the present project, we undertook systematic examination of the synoptic-scale meteorological conditions associated with the occurrence of high concentrations of ozone in the SoCAB. In this regard we acquired gridded temperature and geopotential height data for the 500, 850, and 1000 mb pressure surfaces for the 1985-96 smog seasons, as well as mean sea level pressure data and 850 mb wind data.

Our databases from the first phase of the project (Blier and Winer 1996) were expanded to include ambient air quality data obtained from both ARB and SCAQMD sources from the 1994 through the 1996 smog seasons. PM_{10} data were acquired and archived, and included both SCAQMD 6-day network sampling data (1986-93), as well as data from the Beta Attenuation Monitor (BAM) and Tapered Element Oscillating Microbalance (TEOM) sampling systems in place at selected SCAQMD sites (1994-96).

We also received industrial emissions data from the SCAQMD for major sources under the Regional Clean Air Incentives Market (RECLAIM) program.

Ozone data for the 1994-96 smog seasons were processed using the data gap analysis methodology developed in Phase I. We have thus now derived and archived a full ozone data set for the 1986-96 smog seasons containing daily-maximum values and hour(s) of occurrence of those values.

Additionally, we received speciated ambient VOC data and ambient speciated non-methane hydrocarbon (NMHC) data from both ARB and SCAQMD sources.

Data obtained from stationary sources under RECLAIM were used to examine day-of-the-week differences in industrial (i.e., stationary source) emissions patterns. These data were from approximately 80 sources that reported daily NO_x emissions from May-September 1996. Because the data were distributed by the SCAQMD "as reported," there were numerous discrepancies that required the exclusion of data for statistically unreliable days.

Vehicle activity data for the SoCAB in the form of hourly traffic count data and "freeway" route data were obtained from the California Department of Transportation (Caltrans) for the period May through September for the years 1989, 1991, and 1993-95.

1.4 Analysis of Weekday/Weekend Differences in Ambient Air Quality

To further investigate differences in ambient air quality between weekdays and weekend days as a means of examining potential carryover effects of emissions, we examined the relationship between average evening (morning) NO_2 and NO_x concentrations and next day (same day) Basin-maximum ozone concentrations. These analyses utilized all 1986-96 smog season data for which at least one station in the subregion of interest reported NO_2 and/or NO_x data for at least 2 hours of the 3 hours considered. Correlations between hourly-average maximum ozone concentration and preceding evening NO_2 and NO_x concentrations were additionally determined for stations within the Coastal/Metropolitan and San Gabriel Valley SoCAB subregions (we here define and consider a single "subregion" comprising both the Coastal and Metropolitan subregions). Finally, we correlated Coastal/Metropolitan and San Gabriel Valley morning NO_2 concentration with same day maximum ozone concentration within these subregions over various time periods.

1.4.1 Weekday O_3 Maximum vs. Previous Evening NO_2 and NO_x Concentrations

We correlated the Tuesday evening 1800-2100 PDT average NO_2 and NO_x ambient concentrations with the Wednesday ozone maximum for both Coastal/Metropolitan and San Gabriel Valley subregions for the 1986-93 smog seasons. Correlation coefficients between weekday evening NO_x and following day Basin-maximum ozone were small, though the NO_2 vs. O_3 correlation coefficients were substantially higher than those for NO_x vs. O_3.

We extended this analysis by examining same day correlations between Wednesday morning (0600-0900 PDT) average ambient NO_2 concentrations and Wednesday afternoon Basin and subregional ozone maxima. As expected (given that NO_2 is a direct precursor to ozone), the correlation coefficients increased.

1.4.2 Weekend O_3 Maximum vs. Previous Evening NO_2 and NO_x Concentrations

To search for evidence of NO_2 carryover which might influence weekend ozone concentrations, we calculated correlation coefficients between the two Friday evening time periods (1800-2100 and 2100-0000 PDT) and Saturday peak ozone for the 1986-96 smog seasons. Correlation coefficients between Friday evening NO_2 and Saturday Basin peak ozone were slightly higher for the 2100-0000 PDT than for 1800-2100 PDT, with a more marked improvement for NO_2 concentrations for the San Gabriel Valley subregion. A continuing trend in this direction (presumably related to the growth in mobile source emissions in the mid-Basin) was indicated when the same analysis was done only for 1994-96.

The results suggest only a modest carryover effect of NO_2 emissions on next day ozone, although the effect appears to have strengthened in the last few years. Finally we examined correlation coefficients between Saturday morning (0600-0900 PDT) NO_2 and subsequent same day Basin and subregional ozone maxima for the 1986-96 smog seasons. Correlation coefficients were larger than when previous evening NO_2 values were used; they were also significantly larger than the corresponding correlation coefficients between Wednesday morning (0600-0900 PDT) NO_2 concentration and Wednesday afternoon Basin and subregional ozone maxima. This weekday/weekend difference is particularly marked for the Coastal/Metropolitan subregion.

The results suggest modest carryover of NO_2 emissions from the Coastal/Metropolitan and San Gabriel Valley subregions may influence the daily ozone maximum either within the subregion itself, or in the Basin as a whole, during the eleven-year period investigated.

1.4.3 Variation in Morning NO_2 Concentration vs. Afternoon O_3 Maximum by Day-of-the-week.

We examined correlations between morning NO_2 (0600-0900 PDT) in the Coastal/Metropolitan and San Gabriel Valley subregions and subsequent same day Basin and subregional ozone maxima to determine trends in daily correlation values throughout the 1986-96 periods, as well as to determine the "responsiveness" of the Basin-maximum ozone to Coastal/Metropolitan and San Gabriel Valley NO_2. Daily correlation coefficients calculated between Coastal/Metropolitan average morning (0600-0900 PDT) ambient NO_2 concentrations and same day Basin ozone maxima are shown in Table 1-1.

Similarly, we examined correlation coefficients between average morning (0600-0900 PDT) NO_2 concentrations within the Coastal/Metropolitan subregion and daily-maximum ozone concentrations <u>within</u> this same subregion (Table 1-2). The resulting correlation coefficients are greater than the corresponding values in Table 1-1.

Table 1-1. Correlation coefficients between daily Basin ozone maximum concentration and average morning (0600-0900 PDT) NO_2 concentrations in the Coastal/Metropolitan subregion.

DAY	1986-1989	1990-1993	1994-1996
Monday	0.47	0.47	0.29
Tuesday	0.34	0.46	0.23
Wednesday	0.37	0.25	0.37
Thursday	0.41	0.27	0.36
Friday	0.52	0.32	0.42
Saturday	0.62	0.46	0.45
Sunday	0.55	0.54	0.42

Table 1-2. Correlation coefficients between daily Coastal/Metropolitan ozone maximum concentration and average morning (0600-0900 PDT) NO_2 concentrations in the Coastal/Metropolitan subregion.

DAY	1986-1989	1990-1993	1994-1996
Monday	0.63	0.58	0.34
Tuesday	0.49	0.61	0.35
Wednesday	0.47	0.42	0.49
Thursday	0.56	0.39	0.53
Friday	0.58	0.42	0.58
Saturday	0.67	0.55	0.53
Sunday	0.71	0.61	0.55

Finally, we compared day-of-the-week changes in correlation values between average morning 0600-0900 PDT ambient NO_2 in the San Gabriel Valley and same day Basin ozone maxima for the three time periods (i.e., 1986-89, 1990-93, 1994-96) over the 1986-96 smog seasons. We could not discern any clear pattern from these data.

In general, our results tend to confirm the findings in the Phase I study (Blier and Winer 1996; Blier et al. 1996) that morning NO_2 correlates best with the ozone maximum in the same subregion, and that Coastal/Metropolitan NO_2 no longer correlates well with the afternoon Basin ozone maximum. This reinforces our earlier conclusions (Phase I project report) that cross-Basin transport of precursors is only modestly important relative to the importance of subregion precursor emission influences on the same subregion peak ozone. It should be noted that ambient measurements at ground level are dominated by motor vehicle emissions and effects of emissions from biogenic and stationary sources cannot be evaluated from this type of analysis.

1.4.4 Variation in Location of SoCAB-Maximum Ozone Concentration by Day-of-the-Week

The spatial variation in location of the daily SoCAB-maximum hourly-average ozone concentrations was investigated in order to characterize possible day-of-the-week effects. For each day in the period 15 June to 15 September 1990-93, the monitoring sites in the Basin were ranked according to the daily-maximum ozone concentration. For both Tuesdays/Wednesdays and Saturdays/Sundays, the highest mean rankings occurred in the San Gabriel Valley, Inland Valley, or at Crestline. The lowest rankings occurred in the Coastal subregion and in Orange County. Compared to weekdays, the San Gabriel Valley sites had slightly higher rankings on the weekends, while the Inland Valley had slightly lower rankings on the weekends. This suggests that there was a tendency for the daily SoCAB-maximum ozone concentration to occur farther west on weekends. This indicates a larger relative reduction in NO_x concentrations (emissions) vs. VOC concentrations (emissions) on weekends, and hence a higher VOC/NO_x ratio on weekends, with corresponding more rapid chemistry.

1.4.5 Variation in Ozone and Ozone-Precursors (including NMHC) by Day-of-the-Week

To determine day-of-the-week differences in ambient concentrations of NMHC, NO_x, and peak ozone, we adopted methods similar to those used by Tran et al. (1996), focusing on the 1994-95 period they did not analyze in their earlier study. The 1994-95 smog seasons exhibited an average 45% reduction in NO_x and a 13% reduction in NMHC from Friday to Saturday at 0600-0900 PDT (Figure 1-2), while the average Basin peak ozone increased an average of 11% from Fridays to Saturdays. Additional decreases in ambient NO_x and NMHC on Sunday led to a slight (~ 6%) decrease in average peak ozone from Saturday to Sunday. Average peak Basin ozone concentrations decreased 12% from Sundays to Mondays despite increases of 45% and 13% from Sundays to Mondays in ambient 0600-0900 PDT NO_x and NMHC concentrations, respectively. These observations are consistent with results obtained by Tran et al. (1996) for earlier years. Basin ozone concentrations increased on Saturdays from Fridays for 60% of the weeks in the 1994-95 period (Figure 1-3), while ambient ozone decreased from Sundays to Mondays for approximately 68% of the weeks in the two-year period. Basinwide 0600-0900 PDT concentrations of both NO_x and NMHC decreased approximately 20% in 1996 over 1995.

In general, these results suggest that temporary reductions in ozone-precursor concentrations coincide with increases in weekend Basin peak ozone levels. However, based on our eleven-year trend analysis, ozone levels in the SoCAB have substantially decreased, coinciding with a decrease in both NO_x and NMHC ambient concentrations. Therefore, as discussed by Tran et al. (1996), the transitory nature of this "weekend effect" does not provide evidence that further NO_x reductions for all days of the week will produce a corresponding increase in ambient ozone concentrations. By "transitory" we refer to the nonlinear effect of emission reductions, with respect to the day before, that seem to influence Saturdays differently than Sundays.

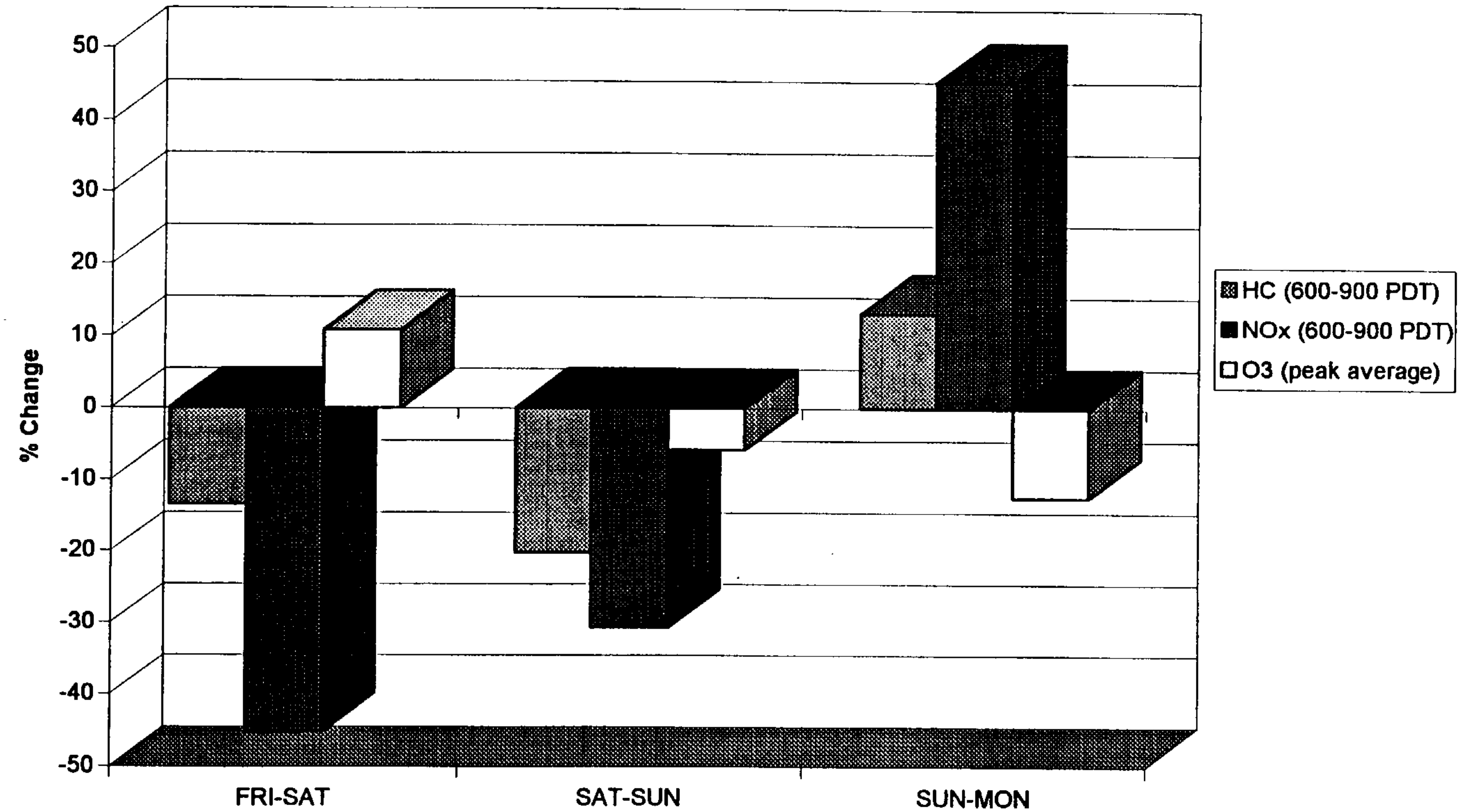

Figure 1-2. Friday-Monday differences in Basinwide peak ozone and ozone-precursors for the 1994-95 smog seasons.

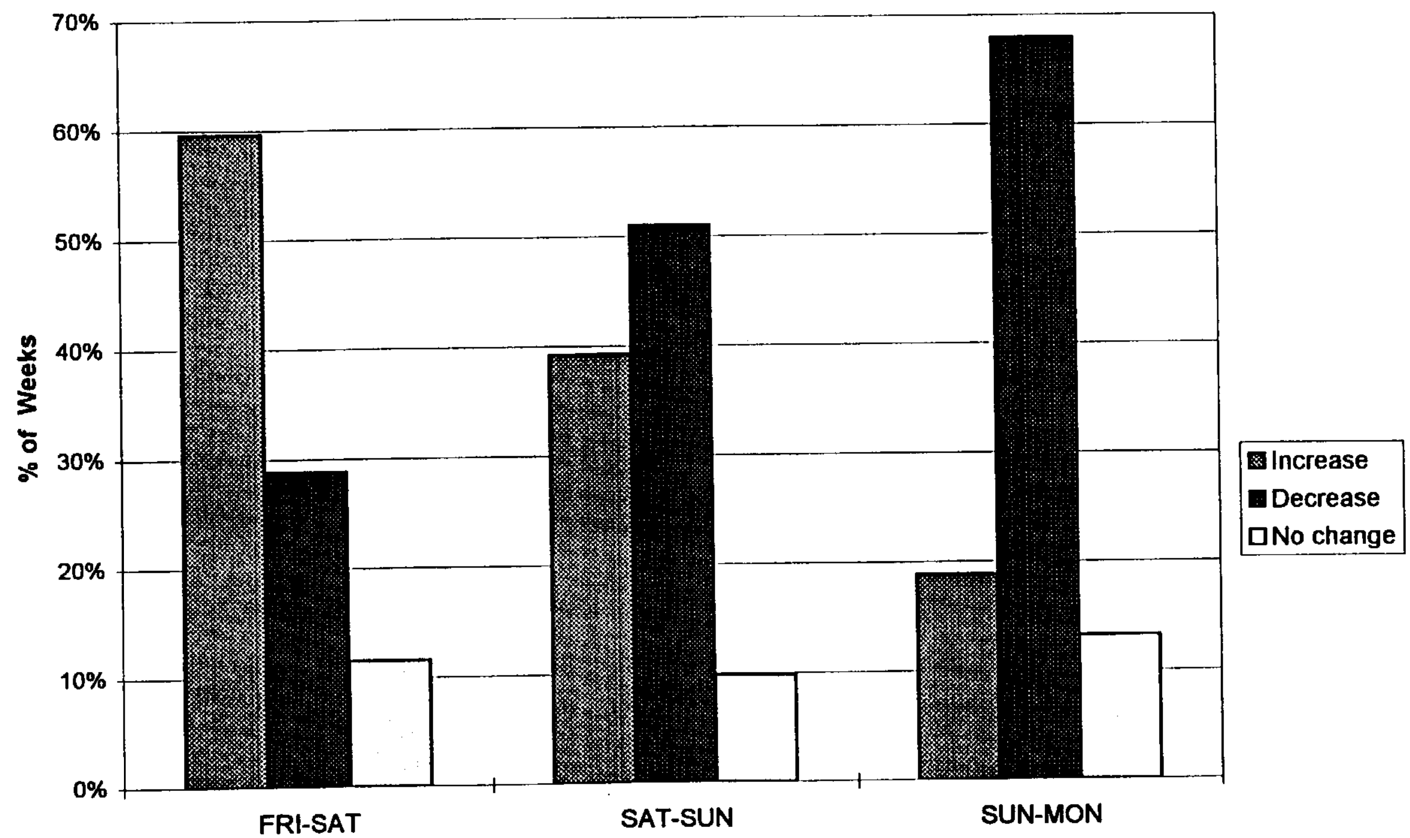

Figure 1-3. Basinwide Friday-Monday differences in peak ambient ozone levels for the 1994-95 smog seasons.

1.5 Investigation of Anthropogenic Influences on Day-of-the-week Variations in SoCAB Meteorological Conditions

1.5.1 Ambient Temperature Analysis

Since urban heat islands are among the most robust and well-documented of anthropogenic meteorological effects, and since it seems physically plausible that in a massively urbanized area such as the SoCAB there could be many human influences that could potentially influence the surface temperature, we felt that if a detectable variation in anthropogenic meteorological influence by day-of-the-week did exist, it would most easily be found in the temperature data. In some sense, too, variations in surface air temperature resulting from human activity should represent the integrative net effect of many of the possible human influences on local meteorological conditions.

We analyzed mean hourly temperature data from 11 SCAQMD air quality monitoring stations well-distributed through the region of the SoCAB. The 3-month interval 15 June to 15 September was considered for each of the five years between 1989 and 1993. For each of the 11 stations, weekday (Tuesday/Wednesday and Wednesday/Thursday) and weekend (Saturday/Sunday) mean temperatures were computed at 4 different times of day: 0500, 1100, 1700, and 2300 PST. The latter were then subtracted from the former to obtain the weekday/weekend temperature differences shown in Table 1-3. Interestingly, with only three minor exceptions, at every station and at each of the four times of day examined, both the average Tuesday/Wednesday temperature and the Wednesday/Thursday temperature were warmer than the corresponding Saturday/Sunday temperature. Thus in 85 of the 88 cases examined, the weekday temperature was warmer than the weekend temperature.

All of these weekday/weekend temperature differences were quite small, however. The average difference (across all stations and times of day) between the Tuesday/Wednesday mean temperature and the Saturday/Sunday mean temperature was 0.6 °F, while that between Wednesday/Thursday and Saturday/Sunday was 0.7 °F.

Table 1-3. SoCAB weekday/weekend differences in mean hourly average temperature from 15 June to 15 September (1989-93). All values in °F; ending time of observation hour indicated.

Site	Time (PST)	Mean T TU/WE	Std.dev. TU/WE	Mean T WE/TH	Std.dev. WE/TH	Mean T SA/SU	Std.dev. SA/SU	Δ T TU/WE -SA/SU	Δ T WE/TH -SA/SU
Anaheim	0500	64.7	3.1	65.1	3.1	65.0	3.2	-0.3	0.1
	1100	78.7	6.3	78.7	6.3	78.1	5.6	0.6	0.6
	1700	78.7	6.0	78.2	7.6	78.3	5.3	0.4	-0.1
	2300	67.3	3.3	66.8	5.7	66.9	3.0	0.4	-0.1
Azusa	0500	63.9	4.4	64.1	4.3	63.2	3.7	0.7	0.9
	1100	79.9	7.5	79.9	7.5	79.1	6.6	0.8	0.8
	1700	82.6	6.2	82.5	5.7	82.0	5.4	0.6	0.5
	2300	67.7	4.7	67.6	4.2	66.8	4.0	0.9	0.8
Burbank	0500	63.6	4.2	63.9	4.2	63.3	3.9	0.3	0.6
	1100	81.4	7.7	81.4	7.7	80.4	6.8	1.0	1.0
	1700	82.1	6.7	82.0	6.0	81.2	6.2	0.9	0.8
	2300	67.0	4.5	66.9	4.2	66.2	3.6	0.8	0.7
Hawthorne	0500	64.2	3.0	64.6	2.9	64.0	2.7	0.2	0.6
	1100	73.5	3.9	73.8	4.1	73.2	4.2	0.3	0.6
	1700	71.0	3.3	71.2	3.3	70.3	3.1	0.7	0.9
	2300	65.1	3.3	65.1	2.9	64.7	2.6	0.4	0.4
LA-Main	0500	64.5	3.9	64.7	3.8	64.1	3.4	0.4	0.6
	1100	79.8	6.8	79.7	6.8	78.7	6.2	1.1	1.0
	1700	76.7	5.6	76.6	5.0	75.7	4.6	1.0	0.9
	2300	66.4	4.1	66.4	3.7	65.6	3.4	0.8	0.8
Long Beach	0500	64.1	2.9	64.4	2.9	64.1	3.0	0.0	0.3
	1100	75.6	5.4	75.5	5.4	74.6	5.0	1.0	0.9
	1700	74.2	4.0	74.3	3.9	73.4	3.8	0.8	0.9
	2300	65.7	3.0	66.0	3.2	65.2	3.0	0.5	0.8
Newhall	0500	59.1	5.0	59.3	5.3	58.6	5.1	0.5	0.7
	1100	87.3	8.4	87.3	8.6	86.2	8.7	1.1	1.1
	1700	89.7	7.0	89.7	7.0	89.3	7.6	0.4	0.4
	2300	67.1	5.4	67.1	5.3	66.1	5.1	1.0	1.0
Pasadena	0500	61.5	4.1	61.7	4.1	61.2	3.9	0.3	0.5
	1100	81.7	7.6	81.5	7.5	80.3	7.1	1.4	1.2
	1700	82.7	6.4	82.7	5.8	81.9	6.0	0.8	0.8
	2300	64.0	3.8	64.1	4.0	63.5	3.7	0.5	0.6
Pico Rivera	0500	63.7	3.7	64.0	3.4	63.7	3.7	0.0	0.3
	1100	80.8	6.3	80.7	6.5	79.7	5.9	1.1	1.0
	1700	80.9	5.5	80.8	4.9	80.1	4.8	0.8	0.7
	2300	66.5	3.7	66.5	3.7	65.8	3.5	0.7	0.7
Riverside	0500	62.4	4.2	62.6	4.3	62.3	4.1	0.1	0.3
	1100	84.0	8.9	84.0	8.7	83.6	7.6	0.4	0.4
	1700	85.6	6.5	85.7	5.8	84.9	6.1	0.7	0.8
	2300	67.9	4.8	67.9	4.7	67.5	4.5	0.4	0.4
Upland	0500	62.4	4.7	62.5	4.8	61.8	4.4	0.6	0.7
	1100	81.5	8.5	81.6	8.4	81.3	7.4	0.2	0.3
	1700	83.4	6.3	83.6	5.7	82.8	5.7	0.6	0.8
	2300	66.5	5.1	66.5	4.8	65.9	4.6	0.6	0.6
Average		**72.7**	**5.2**	**72.7**	**5.2**	**72.1**	**4.8**	**0.6**	**0.7**

A long-term trend analysis of the mean weekday (Monday through Friday) daily-maximum temperature at Los Angeles Civic Center for the 1949-94 smog seasons revealed a gradual increase in the mean smog season daily-maximum temperature during this 46-year period of about 2 °F for both weekdays and weekends. This suggests the urban heat island effect intensified during the 11-year period of the present investigation. It should be noted that the urban heat island effect applies mostly to minimum temperatures and does not affect maximum daily temperatures.

1.5.2 Analysis of Additional Meteorological Variables

We examined relative humidity data for an anthropogenic weekday/weekend effect, using the same 11 SCAQMD air quality monitoring stations and the same time period: the 3-month interval 15 June to 15 September for the five-year period 1989-93. Our results indicated a slight average increase in relative humidity on weekends (0.4%), but unlike the temperature analysis there was no consistency in sign either between the various stations or the different times of day. In addition, the standard deviations were much larger than the weekday/weekend relative humidity differences alone. Thus no day-of-the-week signal was evident.

Given that day-of-the-week differences in air quality have been documented in the SoCAB, it was hypothesized there could be a detectable variation in anthropogenic influence on visibility. We thus proceeded to analyze SCAQMD hourly-average b_{scat} data. Unfortunately, these b_{scat} data were available for only a few sites and for only some of the years during the 1986-96 smog seasons. At Upland, a somewhat lower b_{scat} value (and thus better visibility) was evident for weekend days for all hours examined except 0400-0500, while at Azusa, the b_{scat} values were also slightly lower on weekend days than on weekdays for each of the four examined hours. These results for Upland and Azusa, however, were not statistically significant, given the large standard deviations.

To further investigate a possible day-of-the-week variation in visibility in the SoCAB, a more recent period (15 June to 15 September 1992-94) was selected. This period was also chosen because there happened to be high data completeness in the b_{scat} data set at Azusa (one of only two sites with available b_{scat} data for that period). Results suggested there was a slight tendency for lower visibility days to occur most often on Friday or Saturday at Azusa during the period 15 June to 15 September 1992-94. This is consistent with our work in the previous phase of the present project, where it was shown that Saturday was the favored day for high ozone episodes in the SoCAB.

We reasoned that if there were an anthropogenic influence on visibility, the signal might be detectable as a day-of-the-week variation in solar radiation intensity. The 1994-96 SCAQMD solar radiation data were available only from Azusa, Pico Rivera, LA-North Main, and Upland; as an initial analysis, we chose to investigate the observations from Pico Rivera. The mean radiation intensity was found to be slightly lower on weekdays (Tuesday/Wednesday) than on weekend days (Saturday/Sunday) for each of the four hours examined, consistent with our findings of weekday/weekend differences in b_{scat}. However, this result is not statistically significant as the standard deviations are much larger than the difference of the means between weekdays and weekends.

1.6 Trends in Ozone and Ozone-precursor Ambient Concentrations

1.6.1 Basinwide Precursor Trends

Following the acquisition of ambient data for the 1996 smog season, we examined Basinwide ozone-precursor trends over the eleven-year period 1986-96. Figure 1-4 shows a generally decreasing trend in 0600-0900 PDT Basinwide ambient NO_2 concentration from 1986 to 1996, with a particularly dramatic decrease in 1996. Similarly, average 0600-0900 PDT Basinwide ambient NO_x concentrations also decreased over the 11-year study period.

We also examined 2100-0000 PDT NO_x and NO_2 concentrations by day-of-the-week over the 11-year study period. A downward trend in NO_x concentration was evident. Similar decreases in NO_2 concentrations occurred over the eleven-year period,

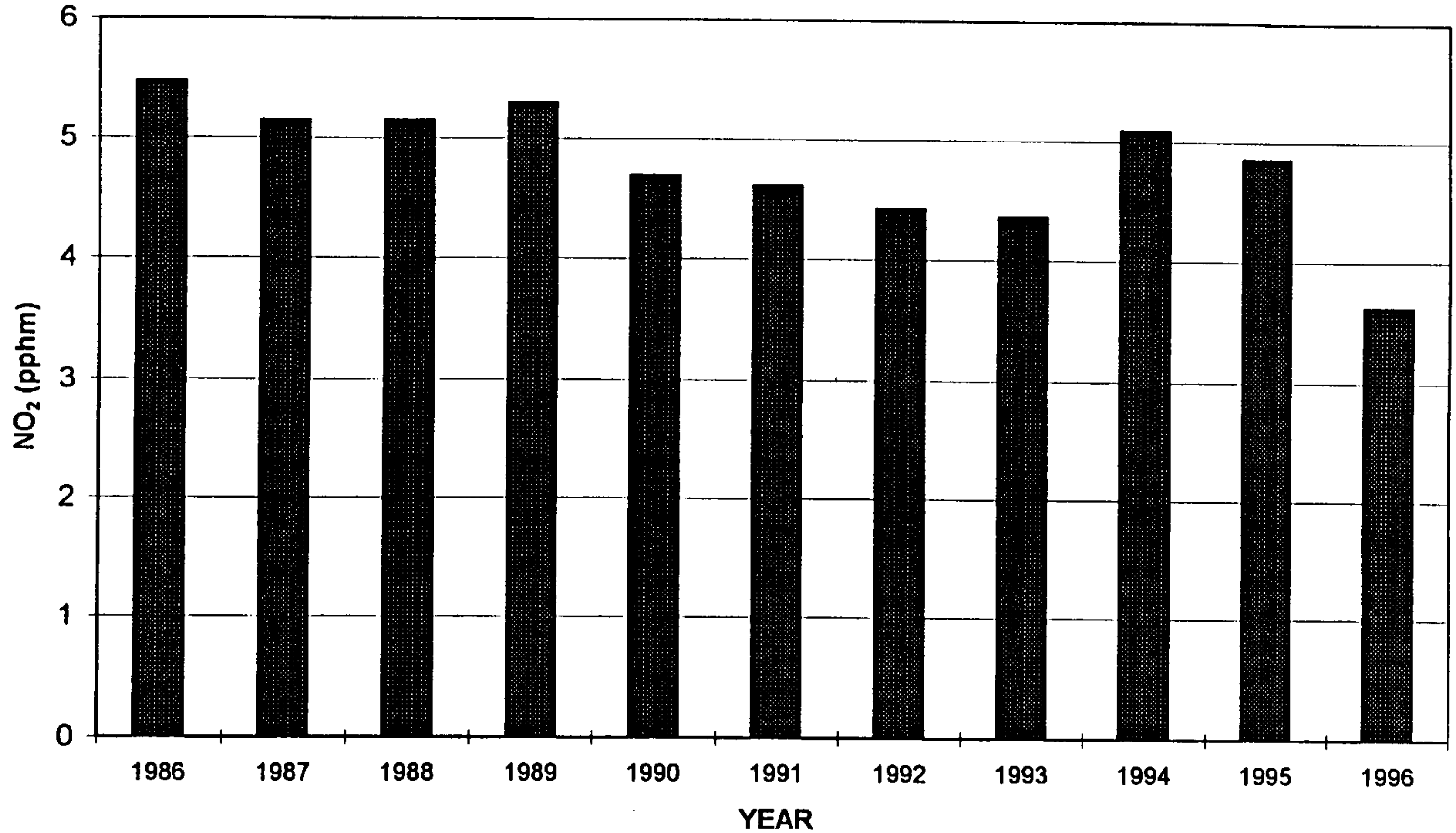

Figure 1-4 Basinwide average ambient NO_2 (pphm) for 0600-0900 PDT May-October 1986-96.

with an approximate 25% reduction for the 1996 smog season over the average for the 1992-95 smog seasons. This reduction may have been responsible, in part, for the corresponding decrease in the number of first stage ($[O_3] \geq 20$ pphm) episodes in the Basin from 13 in 1995 to 7 in 1996. In addition, the early evening (1800-2100 PDT) NO_2/NO_x ratio decreased significantly in 1996.

A general decrease in 0600-0900 PDT NMHC over the ten-year period 1986-95 was evident for all days of the week. Unfortunately, we could not include the 1996 smog season since THC monitoring was discontinued after the 1995 smog season.

1.6.2 Ozone Trends: 1986-96

The general trend for ozone during the 1986-96 period was toward an increasingly lower number of hours and days of exceedance, at all concentration levels. In particular, there was a substantial reduction in number of hours of *peak* ozone levels (i.e., hours with ozone concentrations at or above 20 pphm). The magnitudes of the percent decreases in number of ozone exceedances were generally much smaller (both hourly and daily) at the lower level of 9 pphm.

Figure 1-5 shows the 20-year trend in stage 1 episodes in the SoCAB. When using this metric, a steady decrease in unhealthful ozone levels can easily be observed over this period. Similar results are also seen in the number of health advisories per year (Figure 1-6), though there was a particularly dramatic decrease from 1996 to 1997. (Note late addition of 1997 data as these just recently became available.)

The percent change (from year-to-year) in number of smog season hours equal or exceeding the ozone NAAQS was computed for three groups of four sites each within the SoCAB for the period 1986-96. Only sites located in the central or eastern part of the Basin were used in this analysis, since year-to-year variation in the small number of ozone NAAQS exceedances which occur in less polluted areas (e.g., Coastal subregion) is likely to be strongly influenced by anomalous meteorological conditions, whereas the variation at the more polluted sites farther inland is likely to be dominated by the effects

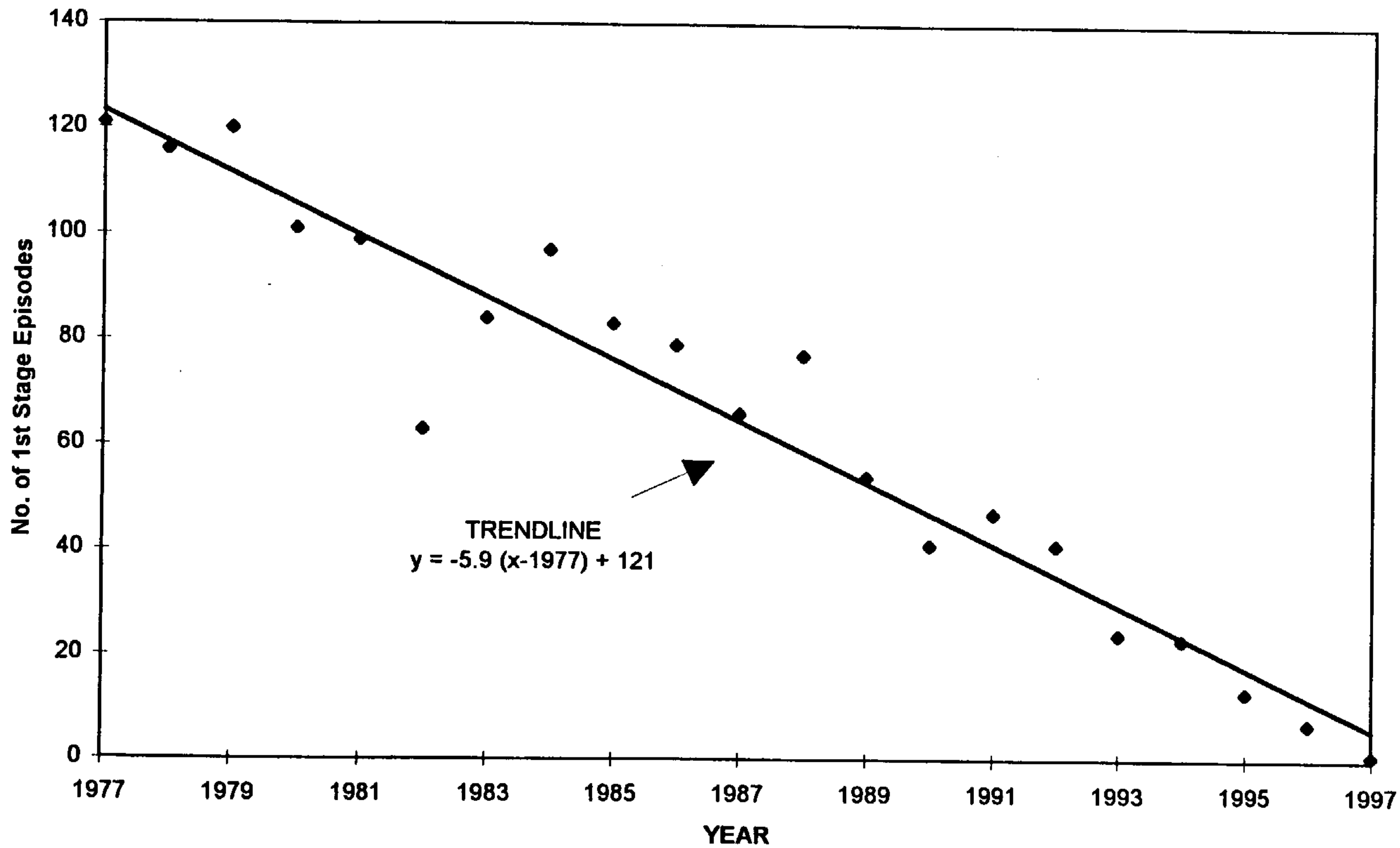

Figure 1-5. SoCAB smog season stage 1 Episodes: 1977-97.

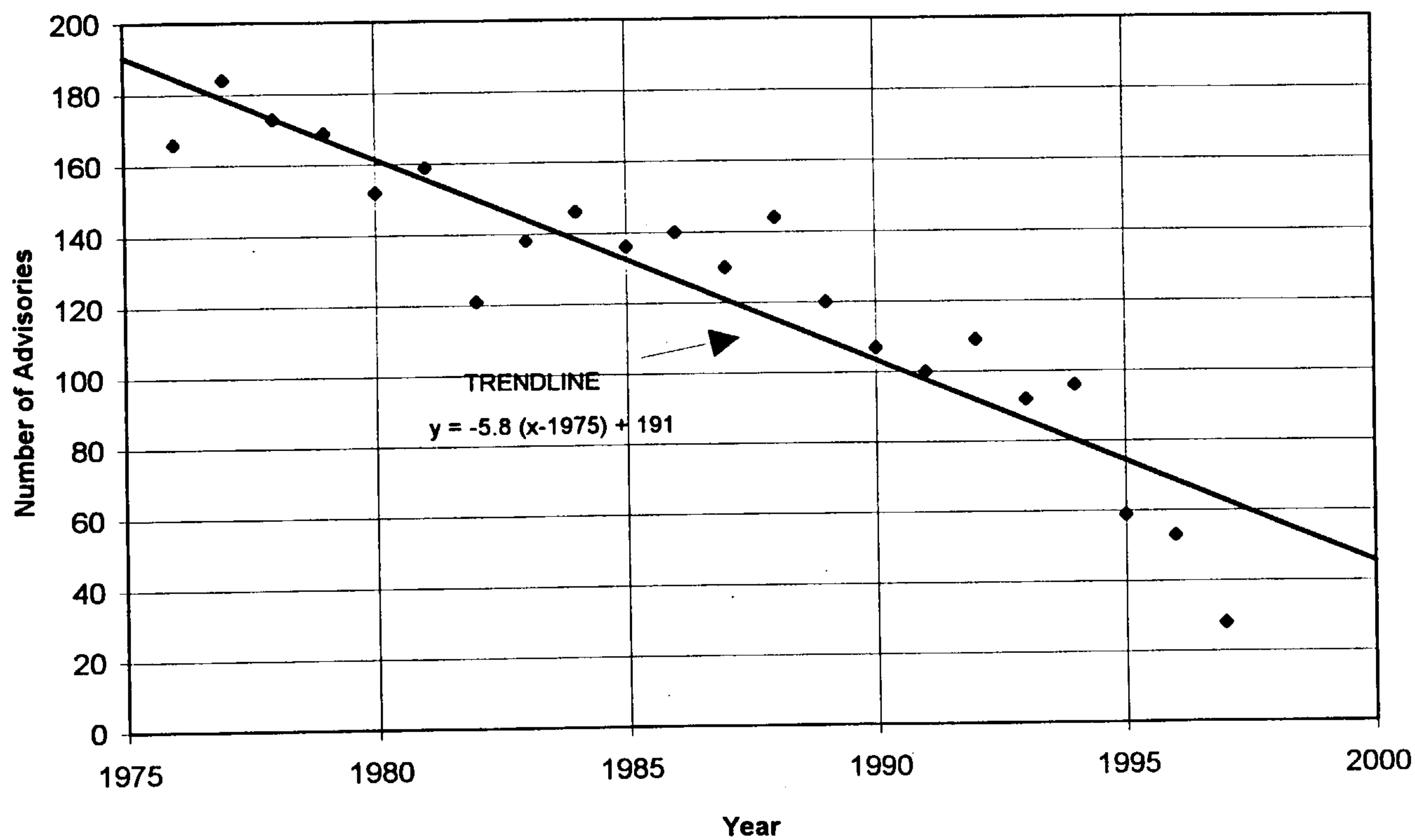

Figure 1-6. Ozone health advisories ($[O_3]$ = 0.15 pphm) 1976-97.

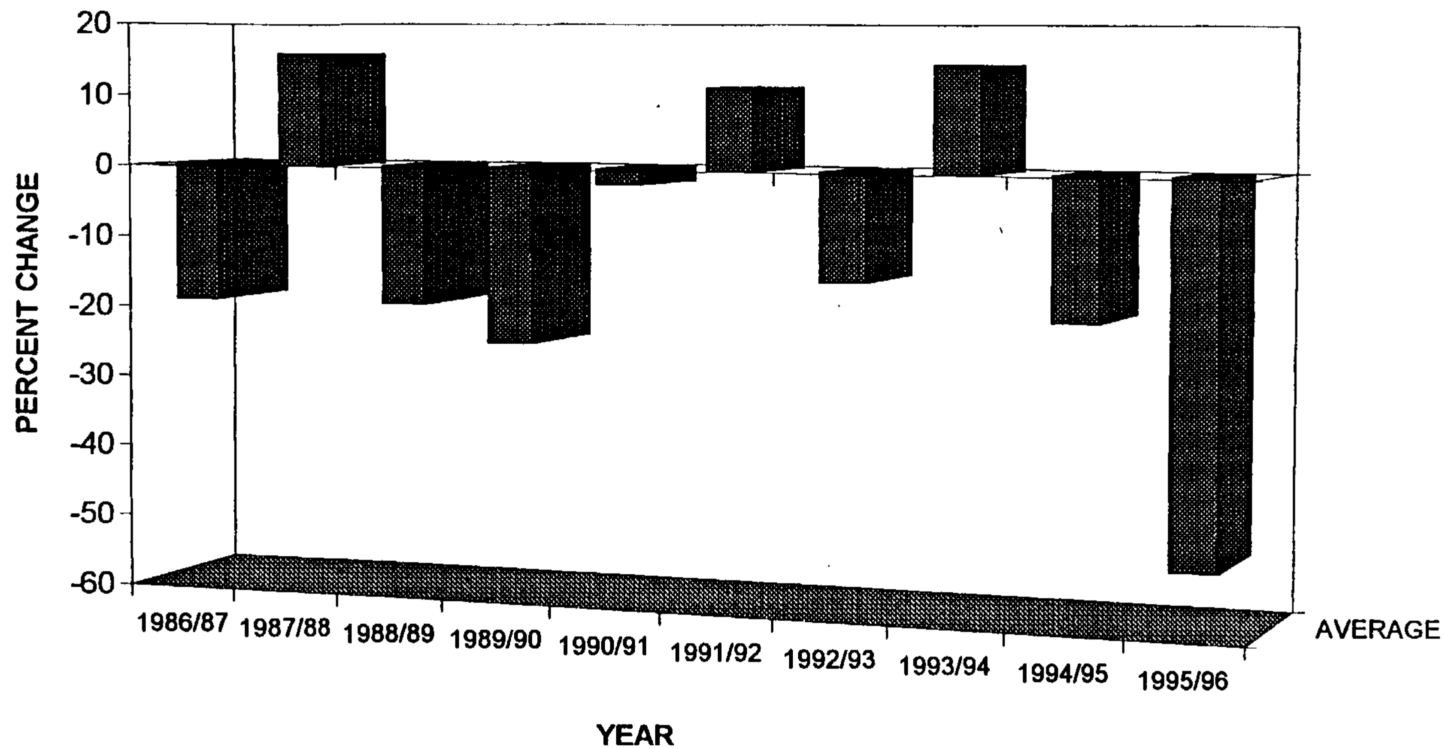

Figure 1-7. Percent change from previous smog season in number of hours equal to or exceeding the ozone NAAQS: average of four mid-basin stations (Azusa, Glendora, Pomona, Upland).

of non-meteorological factors such as reduction in emissions. Results for four mid-Basin sites are shown in Figure 1-7. It was in this part of the SoCAB that a particularly significant reduction in ozone exceedances occurred between 1995 and 1996. The introduction of RFG with lower mass emissions of VOC and lower VOC reactivity throughout the Basin may have been largely responsible. A more extensive analysis is required to properly estimate the RFG.

1.6.3 Recent Changes in Precursor Concentrations

There was a substantial decrease in both NO_x and NO_2 in 1996 vs. 1994-95 for all days of the week, with weekend days having lower average ambient NO_x and NO_2 concentrations than weekdays. A smaller decrease in the NO_2/NO_x ratio also occurred.

1.6.4 1995-96 Smog Season Meteorological Conditions vs. Climatology

With the exception of May and June of 1995, the 1995-96 smog seasons appear to have recorded near or above normal surface temperatures in the central and eastern portions of the SoCAB. These conditions would seem to favor normal to above normal photochemical smog production rates. This conclusion also follows from analysis of gridded 850 mb temperatures at a grid point near the SoCAB which showed near or above normal temperatures for the 1995-96 smog seasons (except during May-June 1995 and September-October 1996, which were cooler than the 1985-96 mean climatological values). Since a substantial *decrease* in the number of ozone exceedances was reported in the San Gabriel Valley (SGV) from 1995 to 1996 (see Table 6-1), and since this decrease was not likely due to meteorological variability, there appears to be evidence of a significant reduction in SGV ozone during the 1995-96 smog seasons resulting from non-meteorological factors.

1.7 Principal Findings

The principal findings of this study were as follows.

- There was some evidence for a stronger carryover effect of Friday evening NO_x on Saturday's Basin-maximum ozone than of Tuesday evening NO_x on Wednesday's Basin-maximum ozone.

- Our results suggested a modest carryover effect of Friday evening NO_2 emissions from the Coastal/Metropolitan and San Gabriel Valley subregions on the Saturday ozone maximum, both within the subregion itself and in the Basin as a whole.

- Morning (0600-0900) NO_2 in the Coastal/Metropolitan and San Gabriel Valley correlates best with the same-day ozone maximum in the same subregion; Coastal/Metropolitan NO_2 no longer correlates well with the afternoon Basin ozone maximum (if it ever did).

- There was a tendency for the daily SoCAB-maximum ozone concentration to occur farther west on weekends.

- Temporary reductions in ozone-precursor concentrations coincided with increases in weekend Basin-peak ozone levels. However, based on our eleven-year trend analysis, ozone levels in the SoCAB have substantially decreased, coinciding with a decrease in both NO_x and NMHC ambient concentrations. Therefore, the transitory nature of the "weekend effect" does not provide evidence that further reduction of the NO_x emission inventory will produce a corresponding increase in ambient ozone concentrations. Here by "transitory" we refer to the fact that weekend weekday effect has not altered the general decline in ozone concentrations.

- Basinwide concentrations of both NO_x and NMHC decreased approximately 20 percent between July through 1995 and July through September 1996. At least some of this decrease, especially for NMHC, may be attributed to the introduction of California Phase 2 reformulated gasoline.

- In 85 of the 88 cases examined, the weekday temperature was warmer than the weekend temperature, while in just 3 cases the weekend temperature was warmer than the weekday temperature. It therefore appears there may be a small difference in temperature between weekdays and weekend days that can be associated with anthropogenic influences.

- A gradual increase in the mean smog season daily-maximum temperature during the 1949-94 period of about 2 °F can be observed for both weekdays and weekends at

Los Angeles Civic Center. This suggests that the urban heat island effect intensified during the period of investigation.

- No day-of-the-week signal was evident for relative humidity.

- Analysis of SCAQMD hourly-average b_{scat} data suggested a slight tendency for lower visibility days to occur most often on Friday or Saturday at Azusa during the period 15 June to 15 September 1992-94.

- At Pico Rivera, the mean radiation intensity was found to be slightly lower on weekdays (Tuesday/Wednesday) than on weekend days (Saturday/Sunday) for each of the four hours examined.

- We examined ozone-precursor trends over the eleven-year period 1986-96 and found an overall modest decrease in 0600-0900 PDT and 2100-0000 PDT Basinwide ambient NO_x and NO_2 concentrations from 1986 to 1995, with a more dramatic decrease from 1995 to 1996.

- Examination of 0600-0900 PDT Basinwide ambient NMHC concentration from 1986 to 1995 revealed a pronounced decreasing trend. A general decrease in 0600-0900 PDT NMHC over the ten-year period from 1986 to 1995 for all days of the week was observed.

- The general trend during the 1986-95 period was toward an increasingly lower number of hours and days of exceedance, at all concentration levels. In particular, there has been substantial reduction in number of hours of *peak* ozone levels (i.e., hours with ozone concentrations at or above 20 pphm).

- The percent change (from year-to-year) in number of smog season hours equal to or exceeding the ozone NAAQS was computed for three groups of four sites each within the SoCAB for the period 1986-96. A dramatic reduction in this metric occurred for the four mid-Basin sites between 1995 and 1996, coinciding with the introduction of RFG Phase II.

- There was evidence of a significant reduction in San Gabriel Valley ozone during the 1995-96 smog seasons resulting from non-meteorological factors. This result is consistent with the substantial decrease in NMHC and NO_x ambient morning concentrations seen for 1996.

2.0 INTRODUCTION AND OBJECTIVES

2.1 Introduction

The air quality in the California South Coast Air Basin (SoCAB) has improved over the past two decades as a direct result of strategic ROG and NO_x control programs mandated and implemented by the California Air Resources Board (ARB) and by the South Coast Air Quality Management District (SCAQMD). Empirical evidence from long-term trend data, for both emission inventories and ambient air quality, suggests that reduction in oxides of nitrogen has been beneficial in reducing peak levels of ozone in the SoCAB. In addition, photolysis of nitrogen dioxide remains the only significant pathway to ozone formation in the troposphere.

However, some Urban Airshed Modeling (UAM) results predict that NO_x control beyond the residual 500 tons per day (TPD) estimated to be needed to meet the National Ambient Air Quality Standard (NAAQS) for PM-10 (or PM-2.5), will lead to increasing ozone in the SoCAB (AQMP Task Force 1994). The apparent contradictions between previous UAM predictions concerning NO_x control and observed air quality trends in which dramatic reductions in ozone concentrations have followed simultaneous NO_x and ROG control, has led to suggestions that UAM inputs may not represent high ozone episode conditions over a sufficiently wide range of meteorological conditions. Specifically, much of the regional modeling for the SoCAB has been conducted for only a few pollution episodes, primarily from the Southern California Air Quality Study (SCAQS) conducted in 1987 or earlier field programs in the SoCAB.

Reliance upon such a small number of episodes has precluded proper consideration of the distinction between weekday and weekend episodes. Recent studies, including prior ARB-sponsored research by the researchers in the present study, have shown that the fraction of total ozone standard violations which occur on Saturdays has been increasing over the past decade (Cassmassi 1994; Blier and Winer 1996; ARB 1994). Because the NO_x inventory is believed to be relatively more reduced on weekends vs. weekdays than is the VOC inventory, it has sometimes been concluded that reductions in NO_x emissions increase ozone, at least in the western part of the SoCAB. Alternatively, however, it may be that the effects of a transient short-term reduction in NO_x such as typically occurs on weekend days are substantially different from a long term trend of reduction in NO_x (Tran et al. 1996). Support for this latter interpretation is provided by the analyses from Blier and Winer (1996) which showed that both maximum percentage decrease in ozone concentration between the smog seasons (i.e., 1 May to 31 October) of the two four-year periods 1986-89 and 1990-93 and maximum percentage decrease in NO_x concentration occurred in the same part of the SoCAB (the Coastal/Metropolitan subregion).

In order to more completely address these issues, it is necessary to consider whether there may be systematic variations in meteorological conditions and pollutant carryover by day-of-the-week. Although a considerable number of studies have documented the occurrence of significant anthropogenic weather modification in urban areas (e.g., Landsberg 1970; Hjelmfelt 1982; Oke 1987; Garbesi et al. 1989; Changnon 1992), we are not aware of any published studies which examined variation in such influence by day-of-the-week for the region of the SoCAB. Similarly, further investigation is needed of the degree to which pollutant carryover varies by day-of-the-week. It has been hypothesized, for example, that the typically higher SoCAB peak ozone levels observed on weekend days result from carryover of No_x, HC, & ozone from the comparatively high-volume Friday afternoon commute combined with the light traffic flow of a typical Saturday morning (Zeldin 1996). In support of this hypothesis, it has been suggested that ozone concentrations typically develop about one hour earlier on Saturdays than on Fridays (Zeldin 1996), but this requires further investigation.

2.2 Objectives

2.2.1 Overall Objectives

The primary overall objectives of this project were: (1) to examine weekday/weekend differences in ambient air quality, and their implications for carryover and other effects; and (2) to investigate weekday/weekend differences in SoCAB meteorological conditions (if any) resulting from anthropogenic influences.

2.2.2 Specific Objectives

The specific objectives of the project were:

- To expand our previous meteorological and ambient air quality databases, developed under ARB support, through inclusion of additional years of data and additional meteorological data and pollutants.
- Using this database, to further characterize recent (*i.e.*, past decade) correlations (or lack thereof) between ozone and previous evening or same day morning NO_2 and NO_x ambient air concentrations. In particular, to further investigate differences in ambient air quality between weekdays and weekend days as a means of identifying whether carryover and/or differences in emissions as a function of day-of-the-week are critical to observed air quality patterns.
- To investigate, for the first time for the SoCAB, whether anthropogenic influences, for example heat island effects and vehicle use patterns (and their resulting particulate emissions), cause differences between SoCAB micrometeorology on weekend days vs. weekdays.
- (Exploratory) To explore the relationship between high ozone episodes in the SoCAB and both concurrent and antecedent meteorological conditions, using synoptic-scale gridded fields of meteorological parameters.

3.0 EXPANSION OF DATABASES

3.1 Overview of Phase I Database

Comprehensive data for the criteria pollutants NO_2, CO, O_3 (obtained as hourly-average observations reported from all air monitoring stations in the SoCAB), PM_{10} (obtained as 24-hour averages once per 6 days) and for key meteorological parameters (Table 3-1) were acquired for the years 1986-93. These data were primarily acquired electronically from two sources: the ARB and the SCAQMD. The data files were transferred to the UCLA Department of Atmospheric Sciences computer system via the Internet, with backup copies of the data files made on an 8 mm data cartridge.

Table 3-1. The air quality and meteorological databases (1986-93) acquired for the South Coast Air Basin.

Criteria Pollutants	Meteorological Parameters
Ozone	Upper air data[1]
Carbon Monoxide	Resultant wind speed and direction[2]
Nitrogen Dioxide	Temperature[2]
PM_{10}	Relative Humidity[2]
TSP	Dew Point[2]
Nitrogen Oxides	FAA data[3]

[1]Data location not indicated.
[2]From SCAQMD sites; not all parameters available for all years.
[3]The FAA data (meteorological data from FAA stations in the region of the SoCAB) could be acquired only for 1987-89.

Comparison of the ozone databases obtained from the ARB and SCAQMD, and analysis of the completeness of the ARB hourly-average ozone concentrations, was performed as described in Blier and Winer (1996).

3.2 Acquisition of Additional Meteorological Data

Many additional surface meteorological data sets have now been acquired and archived. SCAQMD meteorological data sets acquired for the 1994-96 smog seasons included hourly-average temperature, dew point, relative humidity, resultant wind speed and direction, maximum wind speed and temperature per hour interval, solar and UV radiation. and visibility. Surface pressure gradient data for 1986-95 was acquired from the SCAQMD. For the years 1991-96, surface airways data were available from the computer archives of the UCLA Department of Atmospheric Sciences. From the California Department of Forestry (CDF), we obtained data for the Remote Automated Weather Stations (RAWS) in the region of the SoCAB for the period 1993-96. Aside from the more mountainous areas surrounding the SoCAB, meteorological data coverage of the Basin is quite good.

Local offshore meteorological buoy data for 1986-93 were received from the National Data Buoy Center. Similar buoy data for 1994 were acquired from archives in the UCLA Department of Atmospheric Sciences, while buoy data for 1 January 1995 through 31 July 1996 were downloaded through the World Wide Web (WWW) from the National Oceanographic Data Center.

Meteorological data for an additional nine sites in Southern California were obtained from the meteorological network maintained by Southern California Edison (SCE). This data set contained hourly observations for the following parameters: temperature, dew point, wind speed and direction, sea level pressure, and solar radiation. The period of record extended from May 1993 to August 1996; quantitative determination of the robustness (i.e., completeness and correctness) of the SCE data set was not undertaken, but cursory inspection suggested a high degree of completeness (approximately 90% or greater) and little erroneous data. The SCE meteorological data were archived, and for greater ease of use were converted from the original comma-delimited format to a fixed-column format. This conversion required the development of a FORTRAN algorithm and its subsequent application to the SCE data. Locations of these sites and other surface meteorological sites in the SoCAB (with some variation in station location and data availability over the 10-year period of investigation) are shown

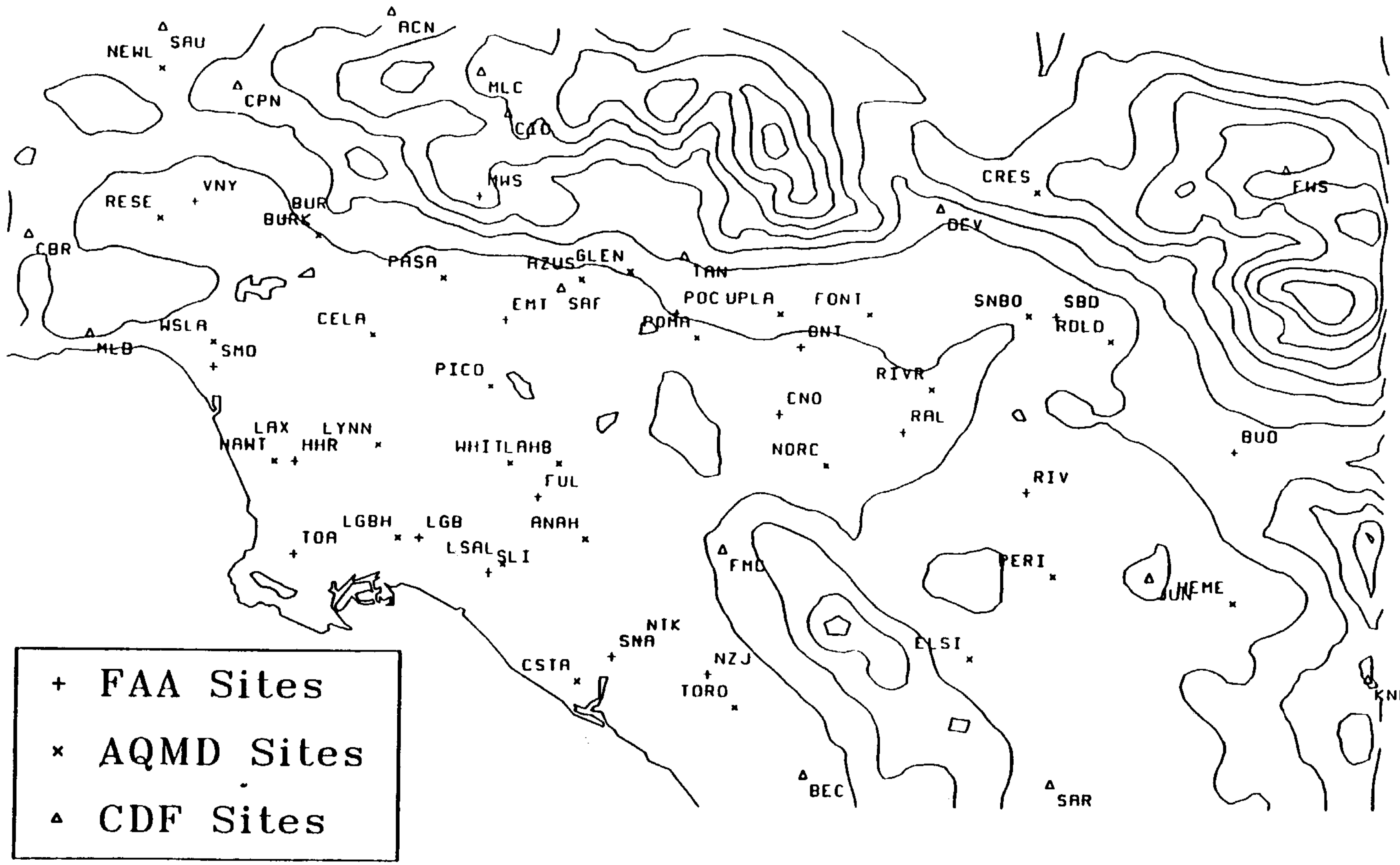

Figure 3-1. Surface meteorological sites in the South Coast Air Basin. Thin solid lines indicate surface elevation at 1000 ft increments.

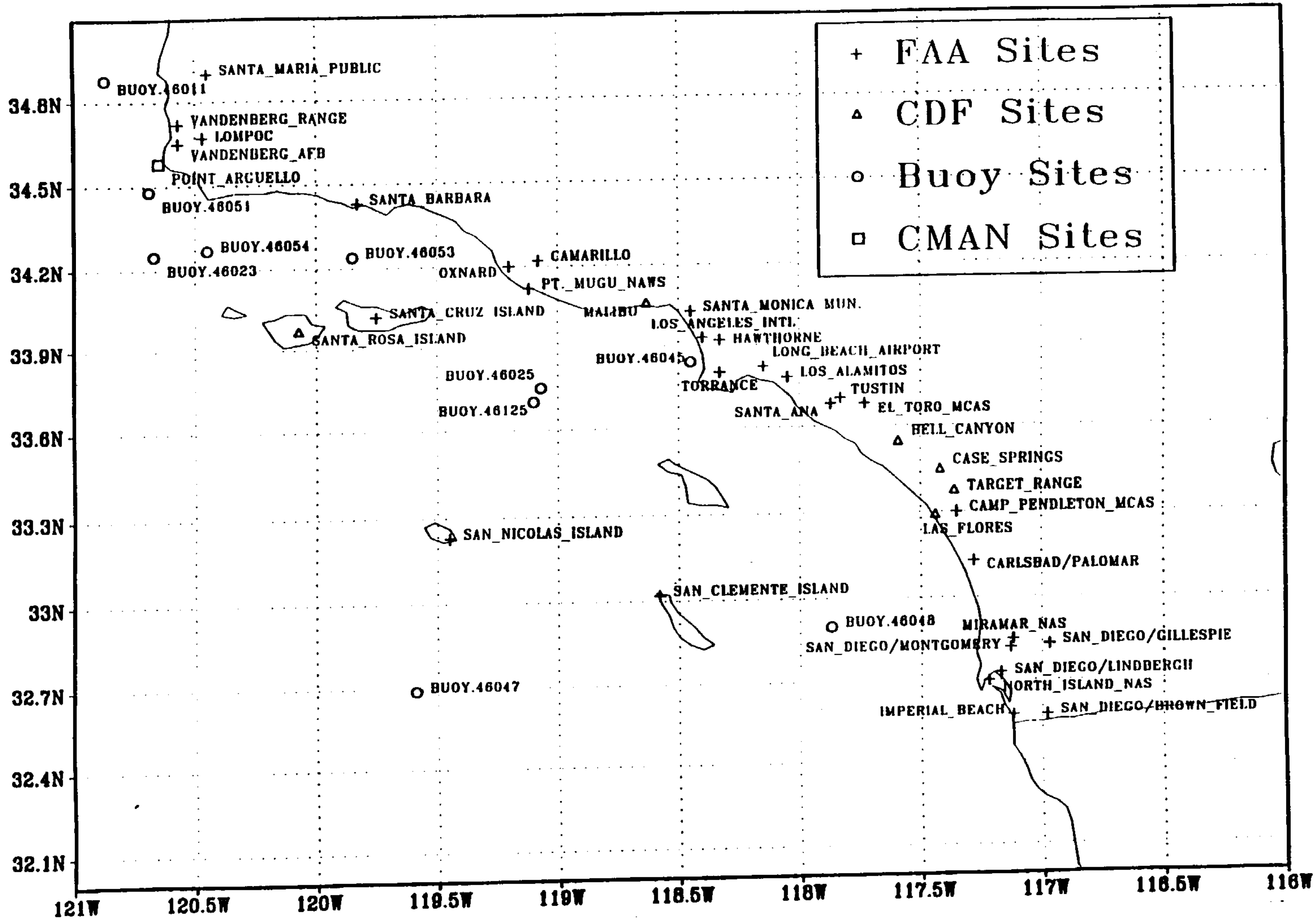

Figure 3-2. Coastal stations with surface meteorological data.

in Figure 3-1, while Figure 3-2 depicts the locations of surface sites for coastal southern California.

Substantial meteorological data were obtained from the ARB. This data set included hourly observations for many observing sites in or near the SoCAB, including Federal Aviation Administration (FAA) meteorological sites and SCAQMD observation sites. The period included the 1986-95 smog seasons. Among the parameters reported were temperature, dew point, relative humidity, visibility, sea level pressure, altimeter setting, and wind speed and direction. The data from the FAA stations were one-minute average observations (typically taken a few minutes before the hour) while those from the SCAQMD sites were hourly-average observations. Completeness of the ARB data set was determined, but appeared to vary widely from site to site. Unfortunately this data set did not contain the latitudes and longitudes of the observing sites, but these could probably be estimated from other sources if necessary.

A significant new addition to our meteorological data archive was the Los Angeles International Airport profiler data for wind and temperature received from the SCAQMD for the period June 1994 to February 1997. As originally received, these data were cumbersome to use due to inconsistent formatting. Therefore, a FORTRAN algorithm was developed and applied to these data to produce two consistently formatted files, one for the temperature data and one for the wind data. Other newly acquired upper air data sets included California sounding data for 1990-96, obtained from the UCLA Department of Atmospheric Sciences archive, the 1987 vertical profiler data (for about 25 days total) from the Southern California Air Quality Study, and soundings from Claremont during the period 2-20 September 1993.

We have also acquired Radar Wind Profiler and Radio Acoustic Sounding System (RWP-RASS) bird-filtered data from the ARB for several sites in Southern California for various periods of time during 1992 (see Table 3-2 for a list of sites and corresponding periods of record). The RASS (RWP) provides vertical profiles of temperature (wind

Table 3-2. The period of record for the sites contained in the RWP-RASS data set.

Location	Period of Record	Data Type
Banning	3/27/92 - 6/24/92	RWP
Barstow	4/28/92 -9/28/92	RWP
El Cajon	8/18/92 - 11/1/92	RWP
Hesperia	4/9/92 - 9/28/92	RWP, RASS
LAX	9/5/92 - 2/8/93	RWP, RASS
Mojave	3/27/92 - 8/10/92	RWP
Palmdale	4/9/92 - 12/12/92	RWP
Point Loma	10/14/92 - 12/31/92	RWP, RASS
Point Mugu	10/3/92 - 12/31/92	RWP, RASS
San Bernardino	4/24/92 - 9/30/92	RWP, RASS
San Clemente Island	10/14/92 - 12/31/92	RWP, RASS
San Diego	5/16/92 - 11/2/92	RWP, RASS
White Water	3/26/92 - 8/11/92	RWP

speed and direction). These data covered too limited a period to be particularly useful in climatological aspects of our investigation.

Climatological daily-maximum and daily-minimum temperatures were acquired for May-October 1986-96 for four sites: Los Angeles International Airport, Los Angeles Civic Center, San Gabriel Fire Department, and San Bernardino County Hospital. These data were obtained from the journal *California Climatological Data* which was published by the National Oceanic and Atmospheric Administration (NOAA) Environmental Data Service of the National Climatic Data Center.

Climatological daily-maximum and daily-minimum temperatures were acquired for the Los Angeles Civic Center for each day of the year in the period 1949-94, from the CD-ROM meteorological data archive at the UCLA Geology Library. The data completeness was greater than 90% for each of the years in this period.

Finally, as an exploratory task in the present project, we undertook systematic examination of the synoptic-scale meteorological conditions associated with the occurrence of high concentrations of ozone in the SoCAB. In this regard we acquired gridded temperature and geopotential height data for the 500, 850, and 1000 mb pressure surface for the 1985-96 smog seasons, from the archive maintained at the National Center for Atmospheric Research. Mean sea level pressure data and 850 mb wind data were also acquired for the same 12-yr period. These data derive from the National Centers for Environmental Prediction (NCEP) Nested Grid Model (NGM) North American Tropospheric Analyses data set, which was produced twice-daily [at 0000 and 1200 Greenwich Mean Time (GMT)]. The data were defined on isobaric surfaces (as well as at sea level) within a limited-domain cartesian grid over a polar stereographic projection of the Earth. Horizontal grid dimensions were 41 by 38, with the distance between the grid points varying from 135 to 203 km (approximately 160 km in the region of southern California). The locations of the grid points are shown in Figure 3-3 Finally, all of these gridded data sets were converted into a more readily-usable format, and then archived on-site as part of the overall project database.

3.3 Acquisition of Additional Air Quality Data

Our databases from the first phase of the project (Blier and Winer 1996) were expanded to include ambient air quality data obtained from both ARB and SCAQMD sources from the 1994 through the 1996 smog seasons. Although in the first phase of this research we used the California Air Resources Board (ARB) air quality data for the 1986-95 smog seasons, 1996 ARB air quality data were not available for use in this research project. Therefore, for 1996, we used the SCAQMD data set in our analyses. The criteria pollutant data were obtained as hourly-average observations reported from all air monitoring stations in the SoCAB. A comparison of ARB and SCAQMD ozone data performed earlier in the project showed little significant difference between the data sets—differences of more than 1 pphm were uncommon (Blier and Winer 1996). As

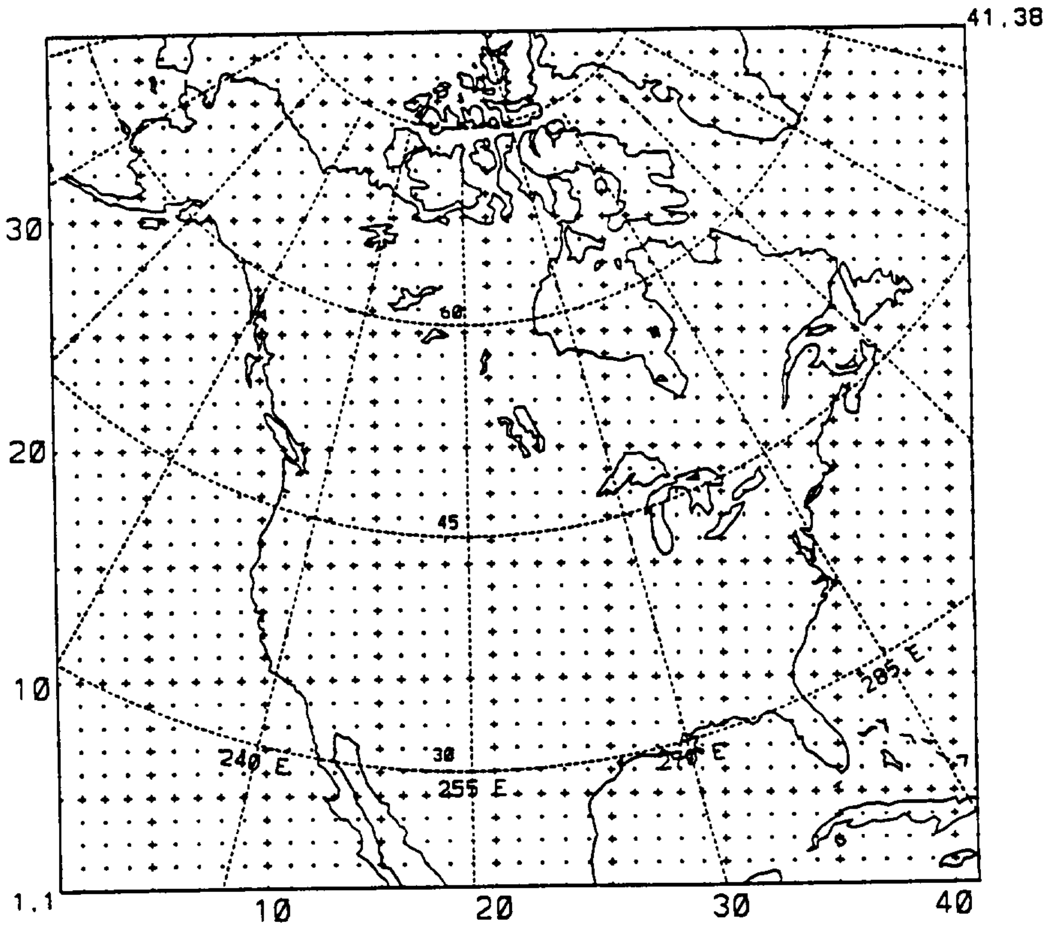

Figure 3-3. Grid point locations for the NCEP-NGM 41x38 grid.

these differences were small, the impact on the results and their implications should be minimal.

PM_{10} data were acquired and archived, and included both SCAQMD 6-day network sampling data (1986-93), as well as data from the Beta Attenuation Monitor (BAM) and Tapered Element Oscillating Microbalance (TEOM) sampling systems in place at selected SCAQMD sites (1994-96). Both continuous BAM and TEOM PM_{10} data were used for diurnal analysis but were not used for trend analysis because they were not consistent with laboratory results from 6-day PM_{10} samples at some locations (Hoggan, 1996). Locations of air quality sites in the SoCAB are shown in Figure 3-4, along with which pollutants are measured at each location.

We also received industrial emissions data from the SCAQMD for major sources under RECLAIM. These sites must report daily emissions of ozone precursors (e.g., NO_x), and thus provide data on day-of-the-week variation in industrial activity and resulting emissions.

In the first phase of the project, daily-maximum hourly-average ozone concentrations were determined for the SCAQMD SoCAB sites for the 1986-93 smog seasons (see Blier and Winer 1996). Prior to undertaking this analysis, however, a methodology was developed to determine whether gaps of missing data on a particular day at a particular site were likely to result in significant uncertainty as to the magnitude of the daily-maximum concentration. In this regard, three tests were applied to the gaps of missing ozone data. A gap of ozone data was considered to be "significant" if that gap failed the application of these tests; under such circumstances the ozone maximum could not be well estimated from the hours for which data were available. With the application of this methodology, a data set was derived which contained the daily-maximum ozone concentrations at all SoCAB sites for the 1986-93 smog seasons. The data set also contained the hour(s) of occurrence of the daily-maximum value at each site for each day.

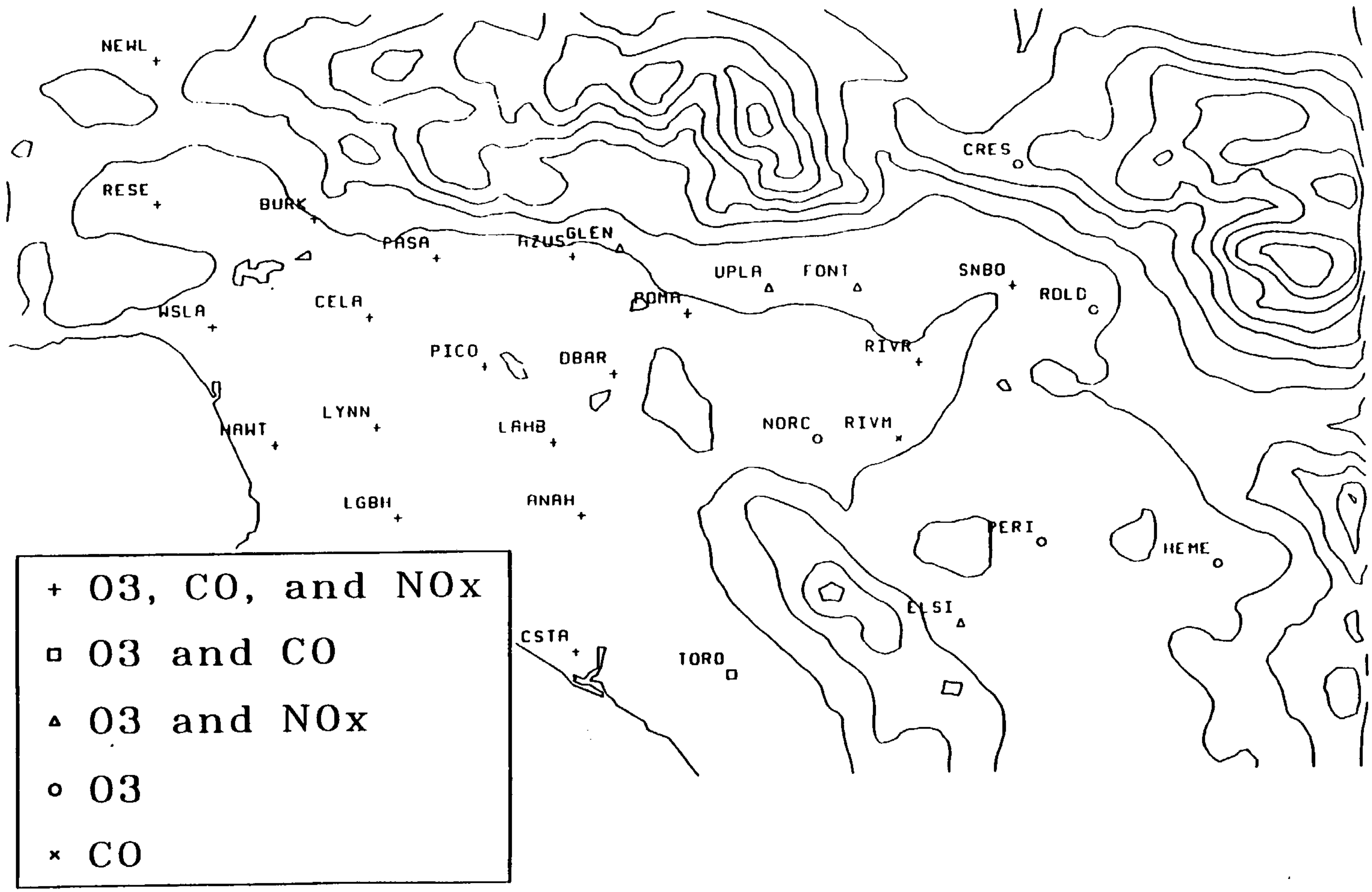

Figure 3-4. Surface air quality sites in the South Coast Air Basin. Thin solid lines indicate surface elevation at 1000 ft increments.

Table 3-3. The fraction of days during the smog season with gaps in ozone data of two or more hours in length. Missing data are denoted by '—'.

Station/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Anaheim	0.07	0.00	0.01	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.03
Avalon	—	—	—	—	0.27	—	—	—	—	—	—
Azusa	0.01	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Beverly Hills	0.32	—	—	0.09	0.16	0.05	—	—	—	—	—
Burbank	0.01	0.03	0.03	0.02	0.02	0.03	0.02	0.01	0.02	0.01	0.02
Chino	0.01	—	—	—	—	—	—	—	—	—	—
Costa Mesa	0.01	0.01	0.26	—	0.02	0.03	0.01	0.01	0.02	0.07	0.00
Crestline	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
Diamond Bar	—	—	—	—	—	—	—	—	0.00	0.01	—
El Toro	0.02	0.02	0.03	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.01
Fontana	0.00	0.01	0.01	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01
Glendora	0.03	0.01	0.02	0.03	0.01	0.00	0.02	0.00	0.00	0.00	0.00
Hawthorne	0.03	0.03	0.02	0.00	0.02	0.01	0.02	0.01	0.02	0.02	0.04
Hemet	0.00	0.03	0.00	0.02	0.02	0.07	0.00	0.01	0.01	0.00	0.93
La Habra	0.01	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Lake Elsinore	—	—	—	0.01	0.01	0.01	0.00	0.02	0.03	0.04	0.00
LA-Main	0.00	0.04	0.03	0.02	0.02	0.03	0.02	0.00	0.01	0.00	0.02
Long Beach	0.08	0.05	0.03	0.01	0.04	0.02	0.01	0.05	0.03	0.01	0.55
Los Alamitos	0.02	0.01	0.09	0.01	0.01	0.01	0.01	0.02	—	—	—
Lynwood	0.08	0.04	0.03	0.03	0.02	0.01	0.02	0.02	0.01	0.03	0.01
Norco	0.01	0.01	0.03	0.01	0.01	0.03	0.01	0.02	0.02	0.01	0.92
Pasadena	0.03	0.01	0.01	0.02	0.01	0.07	0.06	0.11	0.01	0.01	0.03
Perris	0.00	0.02	0.01	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00
Pico Rivera	0.01	0.02	0.02	0.01	0.00	0.01	0.01	0.03	0.03	0.03	0.02
Pomona	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.02
Redlands	0.82	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.16	0.03	0.00
Reseda	0.00	0.05	0.04	0.03	0.02	0.04	0.02	0.01	0.01	0.01	0.02
Riverside	0.01	0.01	0.04	0.00	0.01	0.01	0.00	0.05	0.01	0.01	0.02
San Bernadino	0.84	0.03	0.02	0.02	0.02	0.00	0.01	0.01	0.00	0.01	0.01
Santa Clarita	0.01	0.03	0.02	0.01	0.06	0.00	0.02	0.00	0.00	0.00	0.01
Santa Clarita	—	—	—	0.05	—	—	—	—	—	—	—
Temecula	—	—	—	—	—	0.83	0.08	0.03	—	—	0.93
Upland	0.02	0.03	0.03	0.01	0.00	0.01	0.01	0.00	0.02	0.00	0.02
West LA	0.01	0.08	0.02	0.01	0.10	0.01	0.02	0.02	0.02	0.12	0.02
Whittier	0.02	0.01	0.02	0.02	0.01	0.00	0.01	0.00	—	—	—

Ozone data for the 1994-96 smog seasons have now been processed using the aforementioned algorithm. We have thus now derived and archived a full ozone data set for the 1986-96 smog seasons containing daily-maximum values and hour(s) of occurrence of those values. The completeness of these data for each year for each station in the SoCAB is shown in Table 3-3.

3.3.1 Speciated Hydrocarbon Data

Additionally, we received speciated ambient VOC data from both ARB and SCAQMD sources; we used these data to investigate hydrocarbon trends for the 1995-96 smog seasons. As in the past, except for a few well-documented intensive monitoring studies (e.g., Fujita et al. 1992), the absence of extensive and accurate ambient VOC concentration data made inferences about emissions problematic.

We acquired ambient speciated non-methane hydrocarbon (NMHC) data from both ARB and SCAQMD sources. The ARB data were retrieved from the Environmental Protection Agency's (EPA) Aerometric Information Retrieval System (AIRS), and from the Desert Research Institute (DRI). The SCAQMD speciated VOC data set was derived from the Photochemical Assessment Monitoring Stations (PAMS). At the time, the only PAMS site was at Azusa in the San Gabriel Valley. A total of eight three-hour samples per day were taken every third day at Azusa from July 1 through September 30, 1996.

The DRI data set was from the Phase 2 Reformulated Gasoline (RFG) Ambient Chemical Concentrations Study and contained speciated data similar to that contained in the AIRS and PAMS data sets, plus data for MTBE, HCHO, and other oxygenates. At LA-North Main (LA-Main), three-hour long samples were taken twice daily starting at 0600 and 1300 PDT every third day from 1 July through 30 September 1990-95. Table 3-4 lists the key parameters for these data sets and shows that the data were limited in the number of sites, sampling periods, and years. In all data sets, benzene, xylenes, and other NMHC species were analyzed by gas chromatographic methods, with their concentrations reported in parts-per-billion as carbon (ppbC), with the exception of MTBE which was reported in parts-per-billion by volume (ppbv).

Table 3-4. Parameters for speciated hydrocarbon data sets.

SITES	AIRS (1990-95)	DRI (1995-96)	PAMS (1996)
LA-Main	600-900 PDT 1300-1600 PDT	600-900 PDT 1300-1600 PDT	—
Burbank	—	600-900 PDT 1300-1600 PDT	—
Azusa	—	600-900 PDT 1300-1600 PDT	Eight 3-hr samples

3.4 Acquisition of Industrial Emissions Data

Data obtained from stationary sources under the SCAQMD Regional Clean Air Incentives Market (RECLAIM) were used to examine day-of-the-week differences in industrial (i.e., stationary source) emissions patterns. These data were from approximately 80 sources, which reported daily NO_x emissions from May-September 1996. Due to problems the SCAQMD experienced in initially developing this database, the 1996 smog season was the most complete year for which emissions data have been archived by the SCAQMD. Therefore, only 1996 data were used to examine patterns of industrial activity by day-of-the-week. Because the data were distributed by the SCAQMD "as reported," there were numerous discrepancies, which required the exclusion of data for statistically unreliable days. The data set contained site number, Source Industrial Code (SIC), longitude, latitude, device number, date, pollutant (NO_x, SO_2), and emissions in pounds per day.

3.5 Acquisition of Vehicle Count Data

Vehicle activity data for the SoCAB in the form of hourly traffic count data and "freeway" route data were obtained from the California Department of Transportation (Caltrans) for the period May through September for the years 1989, 1991, and 1993-95. Because of the enormous size of these data sets, only these years were chosen, and furthermore, the used data were limited to the May-September period, as well as only to non-freeway state routes. In the region of the SoCAB, the most robust data were available for District 7, which includes Los Angeles County; limited data were also obtained from District 8 (Riverside and San Bernardino Counties) and District 12 (Orange County). In general, these data were of limited usefulness in meeting the objectives of the study.

4.0 ANALYSIS OF WEEKDAY/WEEKEND DIFFERENCES IN AMBIENT AIR QUALITY

To further investigate differences in ambient air quality between weekdays and weekend days as a means of examining potential carryover effects of emissions, we examined the relationship between average evening or morning NO_2 and NO_x concentrations and next day or same day Basin-maximum ozone concentrations. These analyses utilized all 1986-96 smog season data for which at least one station in the subregion of interest reported NO_2 and/or NO_x data for at least 2 hours of the 3 hours considered.

Since the evening NO_2 and NO_x emissions within a given subregion might also contribute to the next day's early morning NO_2 and NO_x concentrations in the same subregion, correlations between hourly-average maximum ozone concentration and preceding evening NO_2 and NO_x concentrations were additionally determined for stations within the Coastal/Metropolitan and San Gabriel Valley SoCAB subregions (we here define and consider a single "subregion" comprising both the Coastal and Metropolitan subregions). Finally, we correlated Coastal/Metropolitan and San Gabriel Valley morning NO_2 concentration with same day maximum ozone concentration within these subregions over various time periods. Table 4-1 lists the air monitoring sites located within the Coastal/Metropolitan, San Gabriel Valley and Inland Valley subregions that were used in all analyses presented in this chapter.

4.1 Weekday O_3 Maximum vs. Previous Evening NO_2 and NO_x Concentrations

To investigate the degree to which evening NO_2 or NO_x emissions from a given subregion influenced the peak ozone concentration in the Basin on the following day, we correlated the Tuesday evening 1800-2100 PDT average NO_2 and NO_x ambient concentrations with the Wednesday ozone maximum for both Coastal/Metropolitan and San Gabriel Valley subregions for the 1986-93 smog seasons. (Here we assume that Tuesday evening vs. Wednesday is generally representative of weekdays.)

Table 4-1. SoCAB air quality monitoring sites used in correlation analyses.

Subregion	Stations
Coastal	Hawthorne Long Beach Los Alamitos West Los Angeles
Metropolitan	Anaheim Burbank Central Los Angeles El Toro La Habra Lynwood Pico Rivera Reseda Whittier
San Gabriel Valley	Azusa Glendora Pasadena Pomona
Inland Valley	Fontana Riverside San Bernardino

As indicated in Table 4-2, correlation coefficients between weekday evening NO_x and following day Basin-maximum ozone were small. Since the NO_2 vs. O_3 correlation coefficients were substantially higher than those for NO_x vs. O_3, our subsequent analyses focused on correlating (average ambient) NO_2 with the peak ozone concentrations.

Table 4-3 shows correlation coefficients between late Tuesday evening (2100-0000 PDT) average ambient NO_2 concentrations and Wednesday Basin and subregional O_3 maximum concentrations over the 1986-93 smog seasons. Although the Coastal/Metropolitan NO_2 vs. O_3 correlation coefficients were unchanged over those for the 1800-2100 period, the NO_2 vs. O_3 correlation coefficients for the San Gabriel Valley subregion increased from 0.28 to 0.40 and from 0.30 to 0.41, respectively, when the later rather than earlier evening period was used.

We extended the above analysis by examining same day correlations between Wednesday morning (0600-0900 PDT) average ambient NO_2 concentrations and Wednesday afternoon Basin and subregional ozone maxima (see Table 4-4). As expected (given that NO_2 is a direct precursor to ozone), the correlation coefficients increased.

Table 4-2. Correlation coefficients between Tuesday evening (1800-2100 PDT) average NO_x and NO_2 concentration and Wednesday ozone maximum (1986-93).

	Coastal-Metropolitan	San Gabriel Valley
Tue NO_x vs. Wed Basin ozone max.	0.07	0.17
Tue NO_2 vs. Wed Basin ozone max.	0.23	0.28
Tue NO_x vs. Wed Subregion ozone max.	0.19	0.20
Tue NO_2 vs. Wed Subregion ozone max.	0.36	0.30

Table 4-3. Correlation coefficients between Tuesday evening (2100-0000 PDT) average NO_2 concentration and Wednesday ozone maximum (1986-93).

	Coastal-Metropolitan	San Gabriel Valley
Tue NO_2 vs. Wed Basin ozone max.	0.23	0.40
Tue NO_2 vs. Wed Subregional ozone max.	0.36	0.41

Table 4-4. Correlation coefficients between Wednesday morning (0600-0900 PDT) average NO_2 concentration and Wednesday ozone maximum (1986-93).

	Coastal-Metropolitan	San Gabriel Valley
Wed NO_2 vs. Wed Basin ozone max.	0.36	0.64
Wed NO_2 vs. Wed Subregional ozone max.	0.47	0.67

4.2 Weekend O_3 Maximum vs. Previous Evening NO_2 and NO_x Concentrations

To search for evidence of NO_2 carryover which might influence weekend ozone concentrations, we calculated correlation coefficients between the two Friday evening time periods (1800-2100 and 2100-0000 PDT) and Saturday peak ozone for the 1986-96 smog seasons. The resulting correlation coefficients are given in Tables 4-5 and 4-6.

Table 4-5. Correlations coefficients between Friday evening (1800-2100 PDT) average NO_2 concentrations at indicated subregions and Saturday ozone maxima for 1986-96; corresponding values for 1986-93 are in parentheses.

	Coastal/Metropolitan	San Gabriel Valley
Fri. NO_2 vs. Sat Basin ozone max.	0.35 (0.37)	0.45 (0.46)
Fri. NO_2 vs. Sat subregion ozone max.	0.40 (0.42)	0.41 (0.41)

Table 4-6. Correlation coefficients between Friday evening (2100-0000 PDT) average NO_2 concentrations at the indicated subregions and Saturday ozone maxima for 1986-96; corresponding values for 1986-93 are in parentheses.

	Coastal/Metropolitan	San Gabriel Valley
Fri. NO_2 vs. Sat Basin ozone max.	0.38 (0.39)	0.56 (0.54)
Fri. NO_2 vs. Sat subregion ozone max.	0.43 (0.45)	0.53 (0.50)

Correlation coefficients between Friday evening NO_2 and Saturday Basin peak ozone were slightly higher for the 2100-0000 PDT than for 1800-2100 PDT, with a more marked improvement for NO_2 concentrations for the San Gabriel Valley subregion. A continuing trend in this direction (presumably related to the growth in mobile source emissions in the mid-Basin) was indicated when the same analysis was done only for 1994-96 (Table 4-7); this yields an even better correlation for the San Gabriel Valley subregion between Friday evening (2100-0000 PDT) NO_2 and Saturday Basin peak ozone than was the case for 1986-96 (0.53).

Correlation coefficients for 1986-93 in Table 4-5 are all greater than corresponding values in Table 4-2, implying that there may be a stronger carryover effect between 1800-2100 Friday and Saturday than between 1800-2100 Tuesday and Wednesday. Comparison of values in Table 4-6 with those in Table 4-3 suggests a similarly large carryover influence between 2100-0000 Friday and Saturday than between 2100-0000 Tuesday and Wednesday (though only NO_2 is examined).

Further interpretation of the weekend correlation coefficients is facilitated by examination of the actual distributions of NO_x and NO_2 vs. ozone. Here we present two sample plots as examples: 2100-0000 PDT Friday evening Coastal/Metropolitan subregion NO_x vs. Saturday ozone maximum within this same subregion (Figure 4-1); and 2100-0000 PDT Friday night San Gabriel Valley subregion NO_2 vs. Saturday Basin ozone maximum (Figure 4-2) for the 1986-96 smog seasons. Although some relationship is evident in Figure 4-1 when Friday evening concentrations of NO_x are relatively low, this does not appear to be the case when NO_x values are higher. In Figure 4-2 there appears to be a somewhat more robust relationship, one which exists for a wider range of values of the independent variable (NO_2). For values above 5 pphm (Coastal) or 8 pphm (San Gabriel), there simply is no relationship.

Table 4-7. Correlation coefficients between Friday evening (2100-0000 PDT) average NO_2 concentrations at the indicated subregions and Saturday ozone maxima for 1994-96.

	Coastal/Metropolitan	San Gabriel Valley
Fri. NO_2 vs. Sat Basin ozone max.	0.34	0.61
Fri. NO_2 vs. Sat subregional ozone max.	0.38	0.57

The results shown in Tables 4-5 to 4-7 suggest only a modest carryover effect of NO_2 emissions on next day ozone, although the effect appears to have strengthened in the last few years.

Finally we examined correlation coefficients between Saturday morning (0600-0900 PDT) NO_2 and subsequent same day Basin and subregional ozone maxima for the 1986-96 smog seasons (Table 4-8). Correlation coefficients are larger than when previous evening NO_2 values are used; they are also significantly larger than the corresponding correlation coefficients between Wednesday morning (0600-0900 PDT)

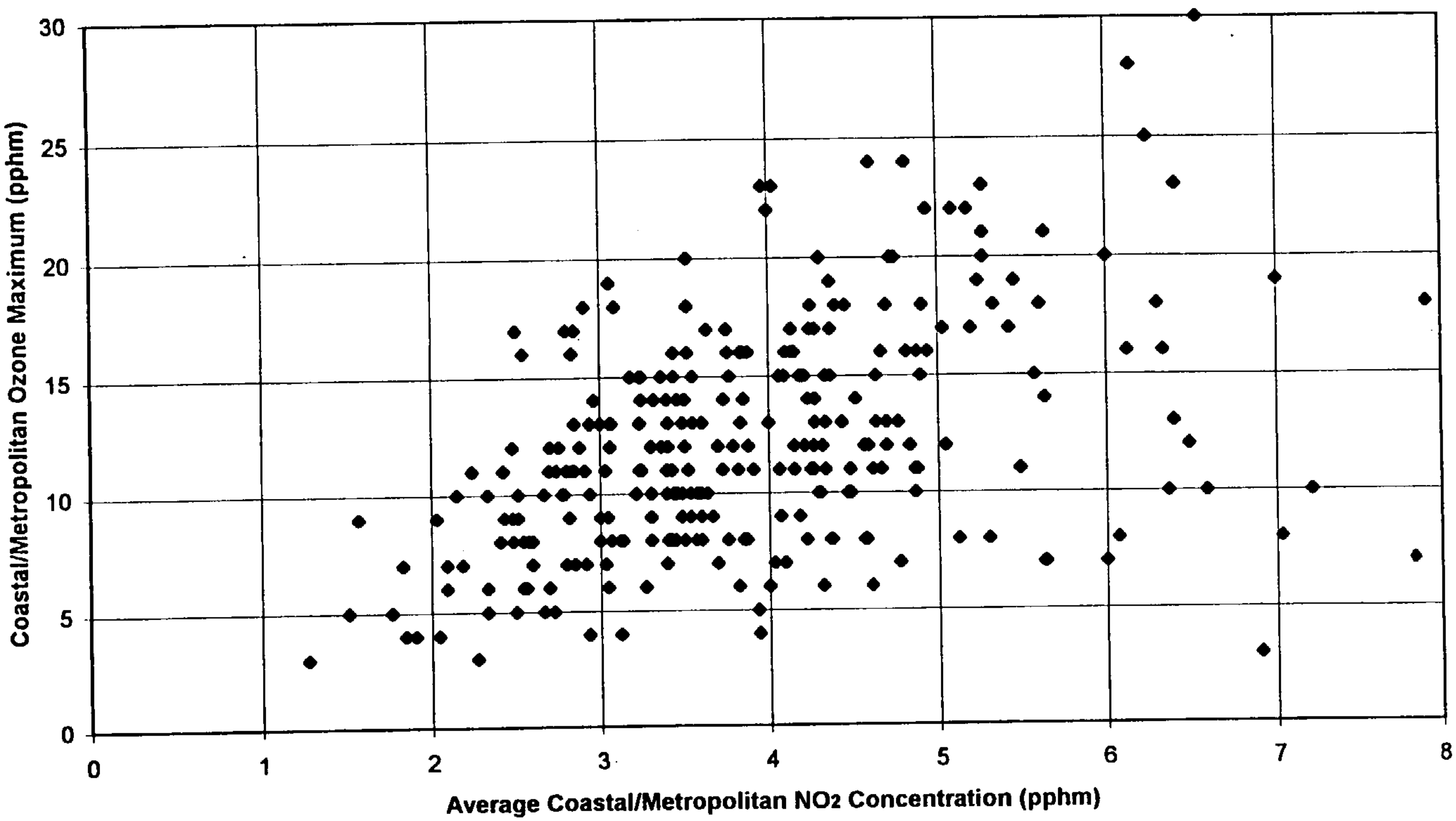

Figure 4-1. Coastal/Metropolitan Friday evening (2100-0000 PDT) NO_2 versus Saturday subregion ozone maximum correlation 1986-96 (Correlatiopn coefficient = 0.43)

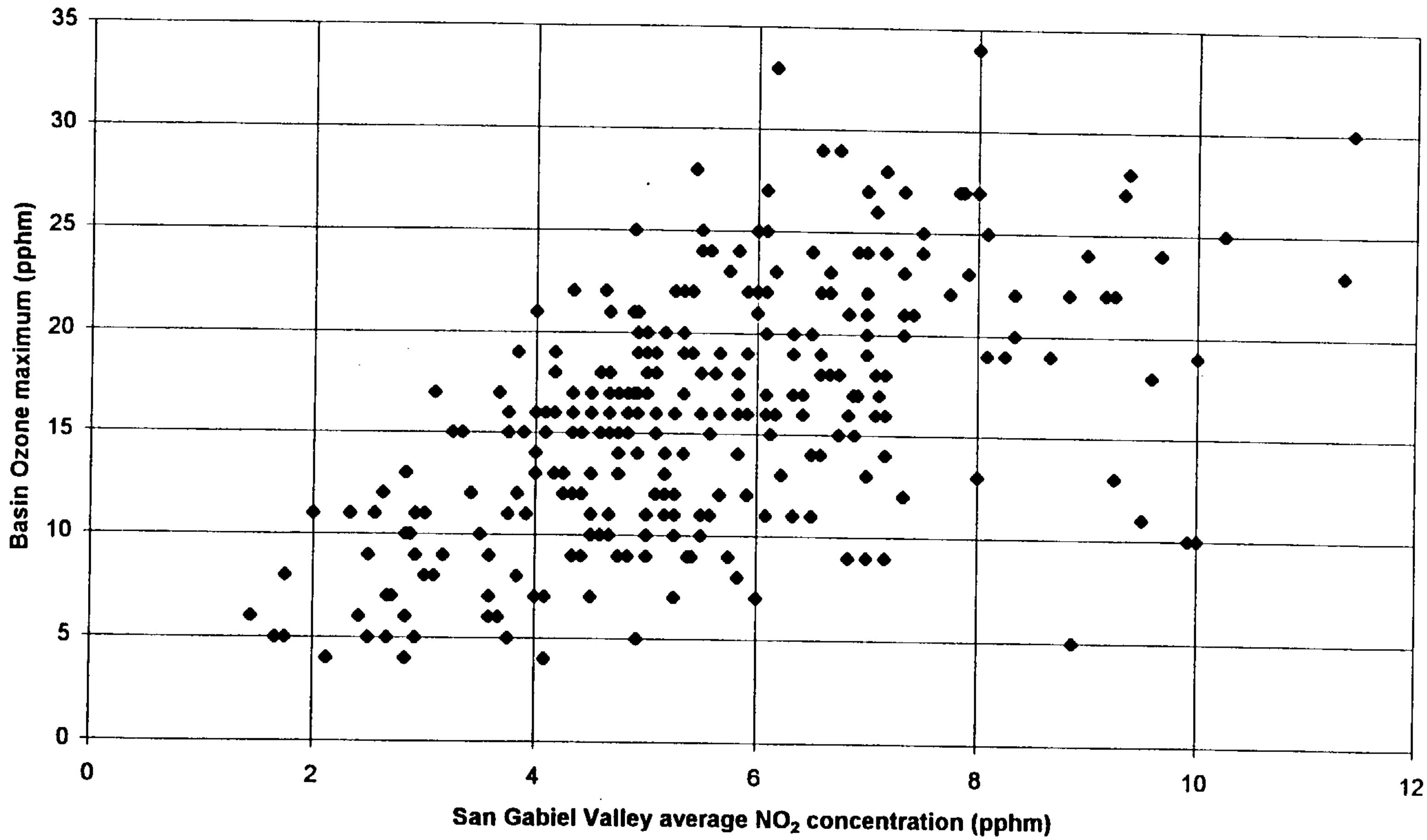

Figure 4-2. San Gabriel Valley Friday night (2100-0000 PDT) NO_2 versus Saturday Basin ozone maximum correlation 1986-96 (Correlation coefficient = 0.56).

Table 4-8. Correlation coefficients between Saturday morning (0600-0900 PDT) average NO_2 concentrations in the indicated subregions and Saturday ozone maxima for 1986-96.

	Coastal/Metropolitan	San Gabriel Valley
Sat. NO_2 vs. Sat Basin ozone max.	0.53	0.71
Sat. NO_2 vs. Sat subregional ozone max.	0.59	0.68

NO_2 concentration and Wednesday afternoon Basin and subregional ozone maxima (Table 4-4). This weekday/weekend difference is particularly marked for the Coastal/Metropolitan subregion. (Note that the similarly relatively large correlations observed between morning San Gabriel Valley NO_2 and Basin-maximum ozone, and morning NO_2 and the maximum ozone value in the San Gabriel Valley, reflect to some degree the frequent occurrence of the daily Basin ozone maximum in or near the San Gabriel Valley.)

The results shown in Tables 4-5 through 4-8 appear to suggest modest carryover of NO_2 emissions from the Coastal/Metropolitan and San Gabriel Valley subregions may influence the daily ozone maximum either within the subregion itself, or in the Basin as a whole, during the eleven-year period investigated.

4.3 Variation in Morning NO_2 Concentration vs. Afternoon O_3 Maximum by Day-of-the Week.

We examined correlations between morning NO_2 (0600-0900 PDT) in the Coastal/Metropolitan and San Gabriel Valley subregions and subsequent same day Basin and subregional ozone maxima to determine trends in daily correlation values throughout the 1986-96 periods, as well as to determine the "responsiveness" of the Basin-maximum ozone to Coastal/Metropolitan and San Gabriel Valley NO_2. Daily correlation coefficients calculated between Coastal/Metropolitan average morning (0600-0900 PDT) ambient NO_2 concentrations and same day Basin ozone maxima over the 1986-89 (Period I), 1990-93 (Period II), and 1994-96 (Period III) smog seasons are shown in Table 4-9. The morning 0600-0900 PDT period was chosen because commuter traffic is at a maximum, and these hours typically exhibit low solar insulation and low wind speeds. Under these conditions, average morning ambient NO_2 concentrations can be assumed to be representative of morning NO_2 emissions.

Table 4-9. Correlation coefficients between daily Basin ozone maximum concentration and average morning (0600-0900 PDT) NO_2 concentrations in the Coastal/Metropolitan subregion.

DAY	1986-1989	1990-1993	1994-1996
Monday	0.47	0.47	0.29
Tuesday	0.34	0.46	0.23
Wednesday	0.37	0.25	0.37
Thursday	0.41	0.27	0.36
Friday	0.52	0.32	0.42
Saturday	0.62	0.46	0.45
Sunday	0.55	0.54	0.42

In the first four-year period, the highest correlations were found on weekends, while correlation coefficients were lowest on Tuesdays and Wednesdays. The weekday/weekend difference in correlation coefficients is somewhat less pronounced in the second four-year period, though values for Wednesday, Thursday, and Friday are still much lower than those for the other days of the week. Substantial reductions in the correlation coefficients for Friday and Saturday occurred between the first two four-year periods. For the 1994-96 period, the correlations between the Coastal/Metropolitan subregion NO_2 and Basin-maximum ozone were generally lower on Saturday through Tuesday, and higher on Wednesday through Friday than for the 1990-93 period. With the exception of Wednesdays, correlation coefficients between the daily Basin ozone maximum and the average morning (0600-0900 PDT) NO_2 concentration in the Coastal/Metropolitan subregion have generally decreased over the eleven-year study period possibly indicating a reduction in the importance of cross-basin pollutant transport relative to the influence of precursor emissions in the mid-Basin area.

Similarly, we examined correlation coefficients between average morning (0600-0900 PDT) NO_2 concentrations within the Coastal/Metropolitan subregion and daily-maximum ozone concentrations within this same subregion (Table 4-10). The resulting correlation coefficients are greater than the corresponding values in Table 4-9.

Table 4-10. Correlation coefficients between daily Coastal/Metropolitan ozone maximum concentration and average morning (0600-0900 PDT) NO_2 concentrations in the Coastal/Metropolitan subregion.

DAY	1986-1989	1990-1993	1994-1996
Monday	0.63	0.58	0.34
Tuesday	0.49	0.61	0.35
Wednesday	0.47	0.42	0.49
Thursday	0.56	0.39	0.53
Friday	0.58	0.42	0.58
Saturday	0.67	0.55	0.53
Sunday	0.71	0.61	0.55

Finally, Table 4-11 compares day-of-the-week changes in correlation values between average morning 0600-0900 PDT ambient NO_2 in the San Gabriel Valley and same day Basin ozone maxima for the three time periods over the 1986-96 smog seasons. We can not discern any clear pattern from these data.

Table 4-11. Correlation coefficients between daily Basin ozone maximum concentration and average morning (0600-0900 PDT) NO_2 concentrations in the San Gabriel Valley subregion.

DAY	1986-1989	1990-1993	1994-1996
Monday	0.65	0.67	0.60
Tuesday	0.61	0.57	0.61
Wednesday	0.61	0.58	0.68
Thursday	0.67	0.65	0.60
Friday	0.75	0.58	0.60
Saturday	0.76	0.65	0.66
Sunday	0.77	0.66	0.67

In general, our results tend to confirm the findings in the Phase I study that morning NO_2 correlates best with the ozone maximum in the same subregion, and that Coastal/Metropolitan NO_2 no longer correlates well with the afternoon Basin ozone maximum. This reinforces our earlier conclusions (Phase I project report) that cross-Basin transport of nitrogen oxides ozone precursors is only modestly important relative to the importance of subregion precursor emission influences on the same subregion peak ozone.

4.4 Variation in Location of SoCAB-Maximum Ozone Concentration by Day-of-the-Week

The spatial variation in location of the daily SoCAB-maximum hourly-average ozone concentrations was investigated in order to characterize possible day-of-the-week effects. For each day in the period June 15 to September 15, 1990-93, the monitoring sites in the Basin were ranked according to the daily-maximum ozone concentration. The site recording the highest hourly concentration in the entire Basin for any given day was given a ranking of 1, the site with the second highest concentration was given a ranking of 2, etc. For days where more than one site recorded the same daily-maximum concentration, the ranking of each of the tied sites was assigned such that the occurrence of ties did not bias the rankings in the direction of either low or high rankings. For example, if the third highest daily-maximum concentration was recorded at four different sites, then a ranking of [(3 + 4 + 5 + 6) / 4], or 4.5 (not 3 or 6) was assigned to the four tied sites. After a ranking was assigned to each site for each day in the period of investigation, the mean of the ranking at each of the sites was computed for Tuesdays and Wednesdays (Figure 4-3) and for Saturdays and Sundays (Figure 4-4). For both Tuesdays/Wednesdays and Saturdays/Sundays, the highest mean rankings occurred in the San Gabriel Valley, Inland Valley, or at Crestline. The lowest rankings occurred in the Coastal subregion and in Orange County. Compared to weekdays, the San Gabriel Valley sites had slightly higher rankings on the weekends, while the Inland Valley had

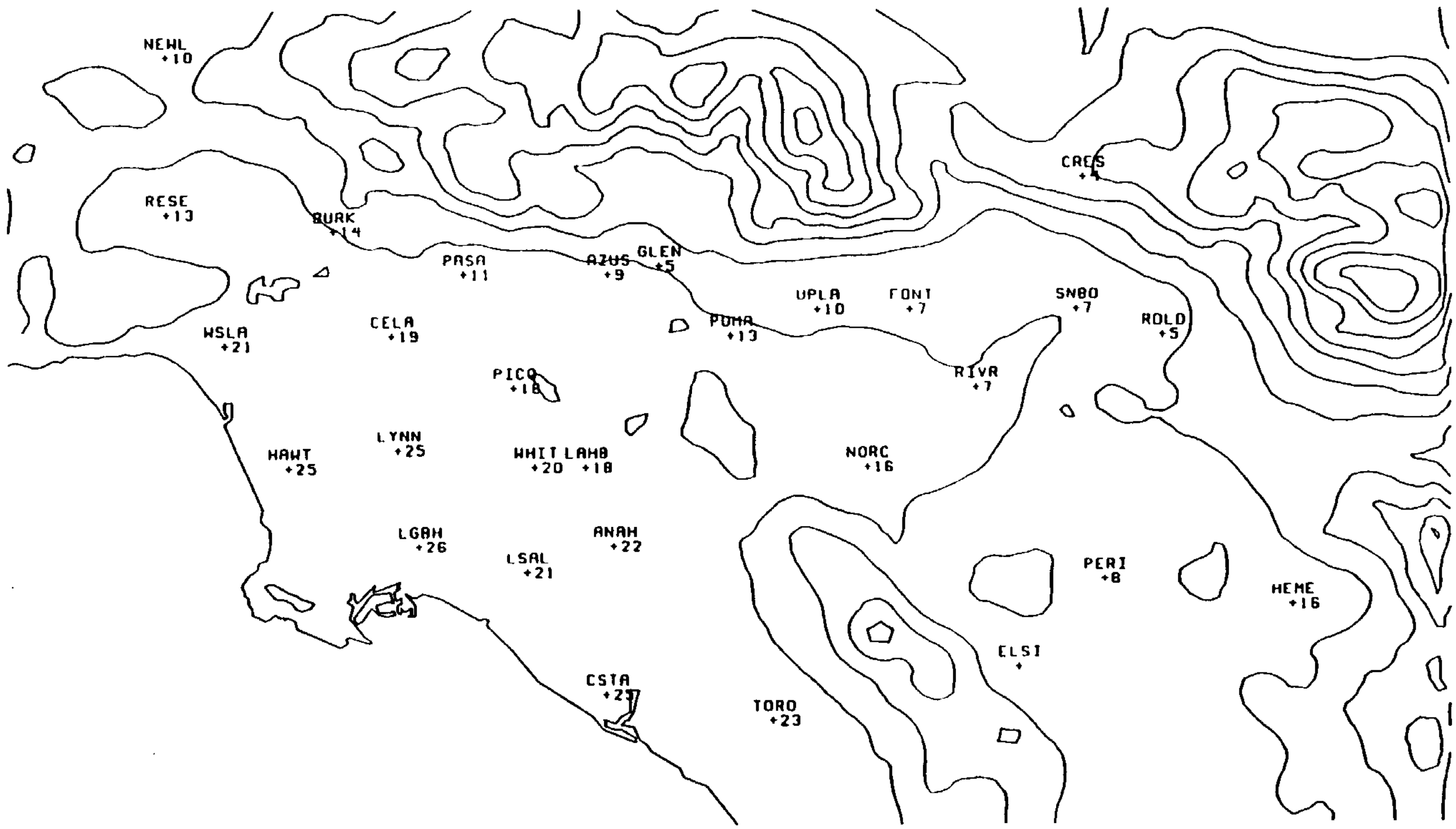

Figure 4-3. Mean of rank of daily SoCAB-maximum ozone concentrations occurring on Tuesday or Wednesday during the period 15 June to 15 September 1990-93.

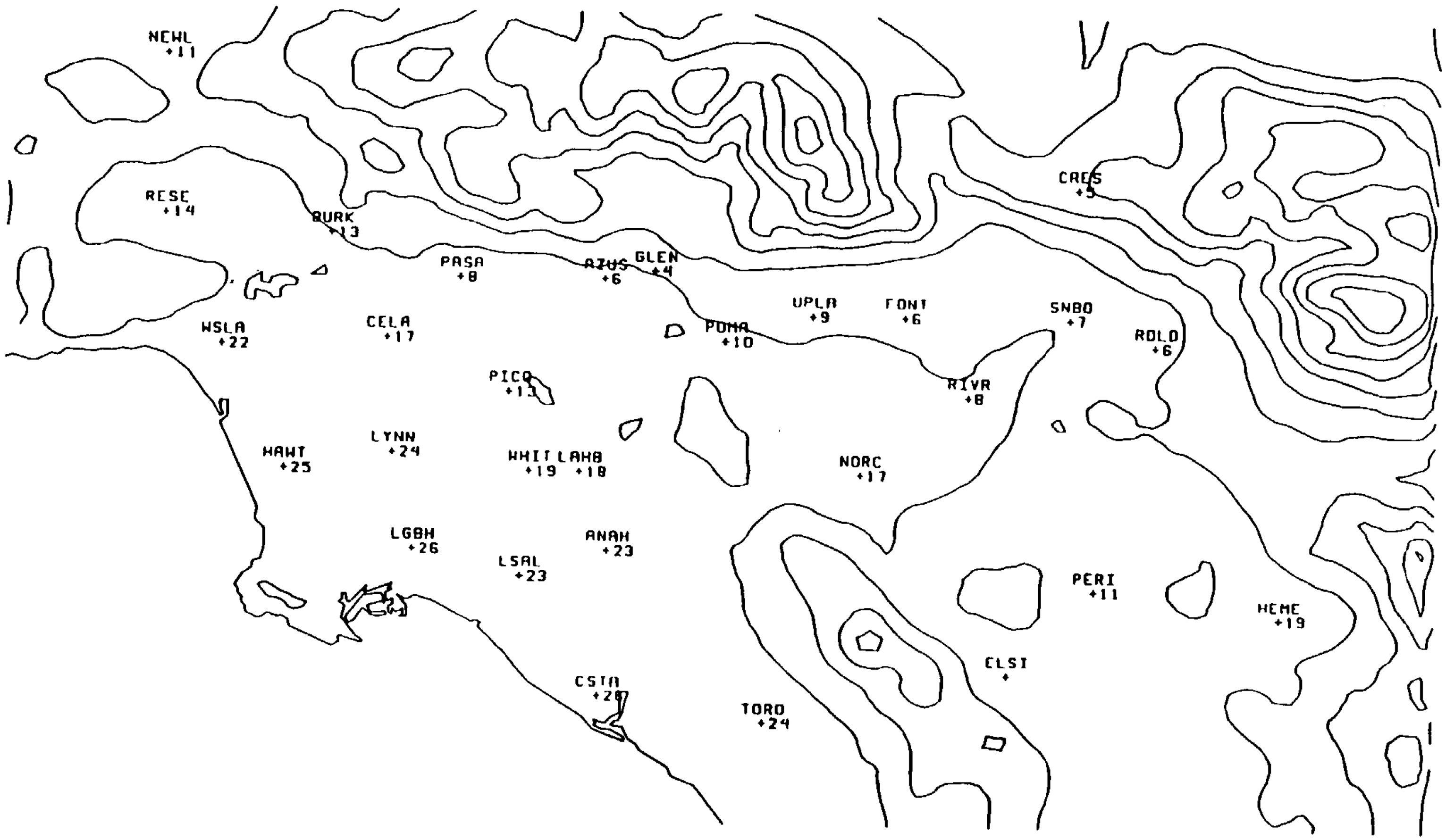

Figure 4-4. Mean of rank of daily SoCAB-maximum ozone concentrations occurring on Saturday or Sunday during the period 15 June to 15 September 1990-93.

slightly lower rankings on the weekends. This suggests that there was a tendency for the daily SoCAB-maximum ozone concentration to occur farther west on weekends. This is directionally consistent with data given below, indicating a larger relative reduction in NO_x concentrations (emissions) vs. VOC concentrations (emissions) on weekends, and hence a higher VOC/NO_x ratio on weekends, with corresponding more rapid chemistry.

4.5 Variation in Ozone and Ozone-Precursors (including NMHC) by Day-of-the-Week

4.5.1 1994-95 Smog Seasons

To determine day-of-the-week differences in ambient concentrations of NMHC, NO_x, and peak ozone, we adopted methods similar to those used by Tran et al. (1996), focusing on the 1994-95 period they did not analyze in their earlier study. Table 4-12 summarizes the percent changes between pairs of days over the Friday-Monday four-day period, normalized to the four-day average for 0600-0900 PDT for the 1994-95 smog seasons (May-October). Ambient total hydrocarbon (THC) data from ARB and SCAQMD were used in calculating daily and four-day average NMHC concentrations for West LA, LA North-Main, Azusa, and Lynwood monitoring sites. Similarly, ambient NO_x concentrations obtained from both the ARB and SCAQMD were used in calculating daily and four-day average NO_x concentrations for these same sites. Interestingly, the four-site 0600-0900 PDT average NO_x, NO_2, and NO concentrations were remarkably similar to the Basin averages shown in Table 4-14.

The 1994-95 smog seasons exhibited an average 45% reduction in NO_x and a 13% reduction in NMHC from Friday to Saturday at 0600-0900 PDT (Figure 4-5), while the average Basin peak ozone increased an average of 11% from Fridays to Saturdays. Additional decreases in ambient NO_x and NMHC on Sunday led to a slight (~ 6%) decrease in average peak ozone from Saturday to Sunday. Average peak Basin ozone concentrations decreased 12% from Sundays to Mondays despite increases of 45% and 13% from Sundays to Mondays in ambient 0600-0900 PDT NO_x and NMHC

Table 4-12. Day-of-the-week differences in 0600-0900 PDT ozone-precursors and corresponding changes in peak ozone for the 1994-95 smog seasons (May-October)

NMHC (ppbC) FROM AMBIENT DATA						**% Change over the 4-Day Average**		
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
WSLA	720	864	1004	1135	930.8	14	-45	15
LA NORTH MAIN	752	804	923	779	814.5	-18	-3	6
AZUSA	352	371	564	423	427.5	-33	-17	4
LYNWOOD	622	836	894	754	776.5	-18	-17	28
					Average	**-14**	**-20**	**13**
NOX (pphm)								
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
WSLA	5.1	8.9	10.0	7.6	7.9	-30	-32	48
LA NORTH MAIN	8.7	14.6	18.5	12.7	13.6	-43	-29	43
AZUSA	5.4	8.4	13.7	8.0	8.9	-64	-29	34
LYNWOOD	6.4	12.3	14.3	9.6	10.7	-44	-30	55
					Average	**-45**	**-30**	**45**
NO2(pphm)								
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
WSLA	2.7	3.3	3.7	3.1	3.2	-19	-13	19
LA NORTH MAIN	4.0	5.1	5.6	4.9	4.9	-14	-18	22
AZUSA	3.6	4.2	5.5	4.5	4.5	-22	-20	13
LYNWOOD	3.2	4.2	4.5	3.7	3.9	-21	-13	26
					Average	**-19**	**-16**	**20**
NO(pphm)								
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
WSLA	2.3	5.6	6.3	4.5	4.7	-39	-47	71
LA NORTH MAIN	4.7	9.5	12.8	7.9	8.7	-56	-37	55
AZUSA	1.7	4.2	8.2	3.4	4.4	-110	-39	57
LYNWOOD	3.1	8.1	9.8	5.9	6.7	-58	-42	74
					Average	**-66**	**-41**	**64**
Average Peak Ozone Concentration								
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
Basin	14.0	12.3	13.3	14.8	13.6	11	-6	-13
Coastal/Metropolitan	10.3	8.7	9.5	10.6	9.8	11	-3	-16
San Gabriel Valley	12.7	10.3	11.7	13.6	12.1	16	-7	-20
Inland Valley	12.9	11.3	12.1	13.7	12.5	13	-6	-13
					Average	**13**	**-6**	**-15**

Table 4-13. Day-of-the-week differences in 0600-0900 PDT ozone-precursors and corresponding changes in peak ozone for the 1994-95 smog seasons (May-October)

NMHC (ppbC) FROM AMBIENT DATA						**% Change Over 2 Day Average**		
SITE	SUN	MON	FRI	SAT		SAT-FRI	SUN-SAT	SUN-MON
WSLA	720	864	1004	1135		12	-45	18
LA NORTH MAIN	752	804	923	779		-17	-4	7
AZUSA	352	371	564	423		-29	-18	5
LYNWOOD	622	836	894	754		-17	-19	29
					Average	**-13**	**-21**	**15**
NOX (pphm)								
SITE	SUN	MON	FRI	SAT		SAT-FRI	SUN-SAT	SUN-MON
WSLA	5.1	8.9	10.0	7.6		-27	-39	54
LA NORTH MAIN	8.7	14.6	18.5	12.7		-37	-37	51
AZUSA	5.4	8.4	13.7	8.0		-53	-39	43
LYNWOOD	6.4	12.3	14.3	9.6		-39	-40	63
					Average	**-39**	**-39**	**53**
NO2(pphm)								
SITE	SUN	MON	FRI	SAT		SAT-FRI	SUN-SAT	SUN-MON
WSLA	2.7	3.3	3.7	3.1		-18	-14	20
LA NORTH MAIN	4.0	5.1	5.6	4.9		-13	-20	24
AZUSA	3.6	4.2	5.5	4.5		-20	-22	15
LYNWOOD	3.2	4.2	4.5	3.7		-20	-14	27
					Average	**-18**	**-18**	**22**
NO(pphm)								
SITE	SUN	MON	FRI	SAT		SAT-FRI	SUN-SAT	SUN-MON
WSLA	2.3	5.6	6.3	4.5		-33	-65	84
LA NORTH MAIN	4.7	9.5	12.8	7.9		-47	-51	68
AZUSA	1.7	4.2	8.2	3.4		-83	-67	85
LYNWOOD	3.1	8.1	9.8	5.9		-50	-62	89
					Average	**-53**	**-61**	**81**
Average Peak Ozone Concentration								
SITE	SUN	MON	FRI	SAT		SAT-FRI	SUN-SAT	SUN-MON
Basin	14.0	12.3	13.3	14.8		11	-6	-13
Coastal/Metropolitan	10.3	8.7	9.5	10.6		11	-3	-17
San Gabriel Valley	12.7	10.3	11.7	13.6		15	-7	-21
Inland Valley	12.9	11.3	12.1	13.7		12	-6	-13
					Average	**12**	**-5**	**-16**

Table 4-14. Average day-of-the-week differences in 0600-0900 PDT oxides of nitrogen and corresponding changes in peak ozone for the 1994-95 smog seasons (May-October)

NOX (pphm)						**% Change Over 4-Day Average**		
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
BASIN	5.3	9.1	11.5	7.8	8.4	-44	-30	45
COAST/METRO	5.8	10.2	12.0	8.5	9.1	-38	-30	48
SAN GABRIEL V	5.1	7.9	11.5	7.2	7.9	-54	-26	35
INLAND VALLEY	5.5	9.0	11.8	7.9	8.6	-46	-28	41

NO2 (pphm)								
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
BASIN	3.2	3.8	4.4	3.8	3.8	-16	-16	16
COAST/METRO	3.1	3.8	4.3	3.7	3.7	-16	-16	19
SAN GABRIEL V	3.3	3.7	4.7	4.1	4.0	-15	-20	10
INLAND VALLEY	3.7	4.2	4.9	4.5	4.3	-9	-18	12

NO (pphm)								
SITE	SUN	MON	FRI	SAT	4-DAY AVG	SAT-FRI	SUN-SAT	SUN-MON
BASIN	2.1	5.3	7	4	4.6	-65	-41	70
COAST/METRO	2.7	6.3	7.7	4.9	5.4	-52	-41	67
SAN GABRIEL V	1.8	4.2	6.8	3.1	4.0	-93	-33	60
INLAND VALLEY	1.8	4.4	7.2	3.9	4.3	-76	-49	60

Peak Ozone Changes

Basinwide	FRI-SAT	SAT-SUN	SUN-MON
Increases	60%	39%	19%
Decreases	29%	51%	68%
No Change	12%	10%	13%

Coastal/Metropolitan Sites	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	58%	43%	15%
% of weeks w/decreases	33%	55%	72%
% of weeks w/no change	10%	2%	13%

San Gabriel Valley Sites	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	63%	43%	17%
% of weeks w/decreases	27%	53%	74%
% of weeks w/no change	10%	4%	9%

Inland Valley Sites	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	60%	37%	21%
% of weeks w/decreases	27%	54%	64%
% of weeks w/no change	13%	8%	15%

Table 4-15. Average day-of-the-week differences in 0600-0900 PDT oxides of nitrogen and corresponding changes in peak ozone for the 1994-95 smog seasons (May-October)

NOX (pphm)					**% Change Over 2 Day Average**		
SITE	SUN	MON	FRI	SAT	SAT-FRI	SUN-SAT	SUN-MON
BASIN	5.3	9.1	11.5	7.8	-38	-38	53
COASTAL/METRO	5.8	10.2	12.0	8.5	-34	-38	55
SAN GABRIEL V	5.1	7.9	11.5	7.2	-46	-34	43
INLAND VALLEY	5.5	9.0	11.8	7.9	-40	-36	48

NO2 (pphm)							
SITE	SUN	MON	FRI	SAT	SAT-FRI	SUN-SAT	SUN-MON
BASIN	3.2	3.8	4.4	3.8	-15	-17	17
COASTAL/METRO	3.1	3.8	4.3	3.7	-15	-18	20
SAN GABRIEL V	3.3	3.7	4.7	4.1	-14	-22	11
INLAND VALLEY	3.7	4.2	4.9	4.5	-9	-20	13

NO (pphm)							
SITE	SUN	MON	FRI	SAT	SAT-FRI	SUN-SAT	SUN-MON
BASIN	2.1	5.3	7	4	-55	-62	86
COASTAL/METRO	2.7	6.3	7.7	4.9	-44	-58	80
SAN GABRIEL V	1.8	4.2	6.8	3.1	-75	-53	80
INLAND VALLEY	1.8	4.4	7.2	3.9	-59	-74	84

Peak Ozone Changes

Basinwide	FRI-SAT	SAT-SUN	SUN-MON
Increases	60%	39%	19%
Decreases	29%	51%	68%
No Change	12%	10%	13%

Coastal/Metropolitan Sites

	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	58%	43%	15%
% of weeks w/decreases	33%	55%	72%
% of weeks w/no change	10%	2%	13%

San Gabriel Valley Sites

	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	63%	43%	17%
% of weeks w/decreases	27%	53%	74%
% of weeks w/no change	10%	4%	9%

Inland Valley Sites

	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	60%	37%	21%
% of weeks w/decreases	27%	54%	64%
% of weeks w/no change	13%	8%	15%

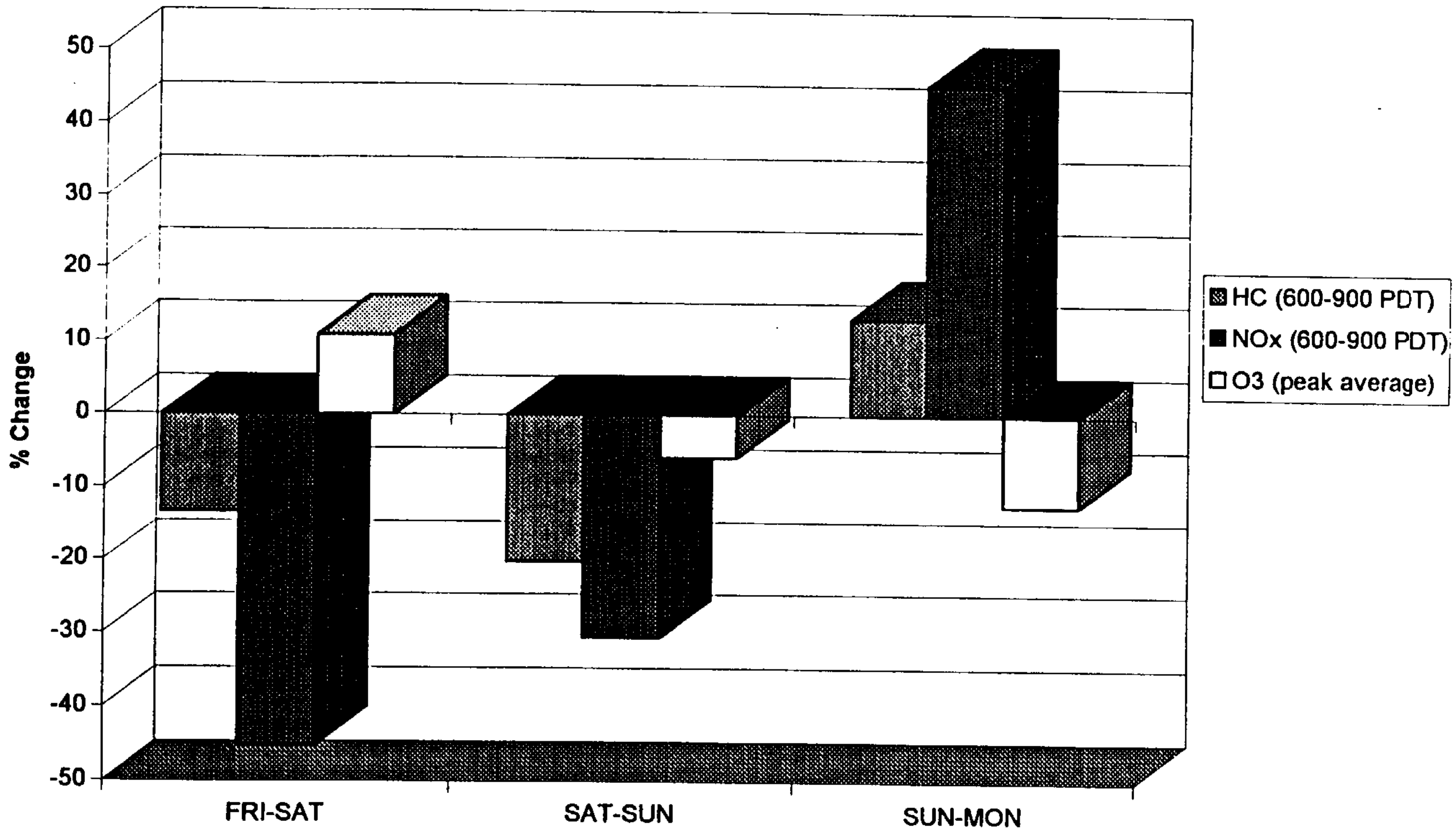

Figure 4-5. Friday-Monday differences in Basinwide peak ozone and ozone-precursors for the 1994-95 smog seasons.

concentrations, respectively. These observations are consistent with results obtained by Tran et al. (1996) for earlier years.

In addition, to the day-of-the-week differences in the Basin, Coastal/Metropolitan, San Gabriel Valley, and Inland Valley oxides of nitrogen, Table 4-14 also shows peak maximum ozone as a percentage of weeks within the 1994-95 smog season in which the peak ozone levels increased, decreased, or stayed the same from day-to-day over the four-day Friday to Monday interval at the SoCAB stations employed. Basin ozone concentrations increased on Saturdays from Fridays for 60% of the weeks in the 1994-95 period (Figure 4-6), while ambient ozone decreased from Sundays to Mondays for approximately 68% of the weeks in the two-year period. A substantial reduction in NO_x with a modest reduction in NMHC resulted in slightly more pronounced Friday to Saturday increases in ambient ozone concentrations for the San Gabriel Valley (63%) than for the Coastal/Metropolitan subregion (58%). In addition 0600-0900 PDT average ambient NO concentrations in the San Gabriel Valley subregion decreased from 6.8 to 3.1 pphm (~ 54%) from Friday to Saturdays. Inland Valley NO concentrations decreased by the same amount (~54 percent) from Saturday to Sunday.

In general, these results suggest that temporary reductions in ozone-precursor concentrations coincide with increases in weekend Basin peak ozone levels. However, based on our eleven-year trend analysis, ozone levels in the SoCAB have substantially decreased, coinciding with a decrease in both NO_x and NMHC ambient concentrations. Therefore, as discussed by Tran et al. (1996), the transitory nature of this "weekend effect" does not provide evidence that further NO_x reductions for all days of the week will produce a corresponding increase in ambient ozone concentrations.

4.5.2 <u>1996 Smog Season.</u>

Table 4-16 summarizes the results of the differences in oxides of nitrogen over July through September for 1994-95 (averaged) to 1996, as well as the differences in speciated NMHC from July-September 1995 to 1996 during 0600-0900 PDT (speciated

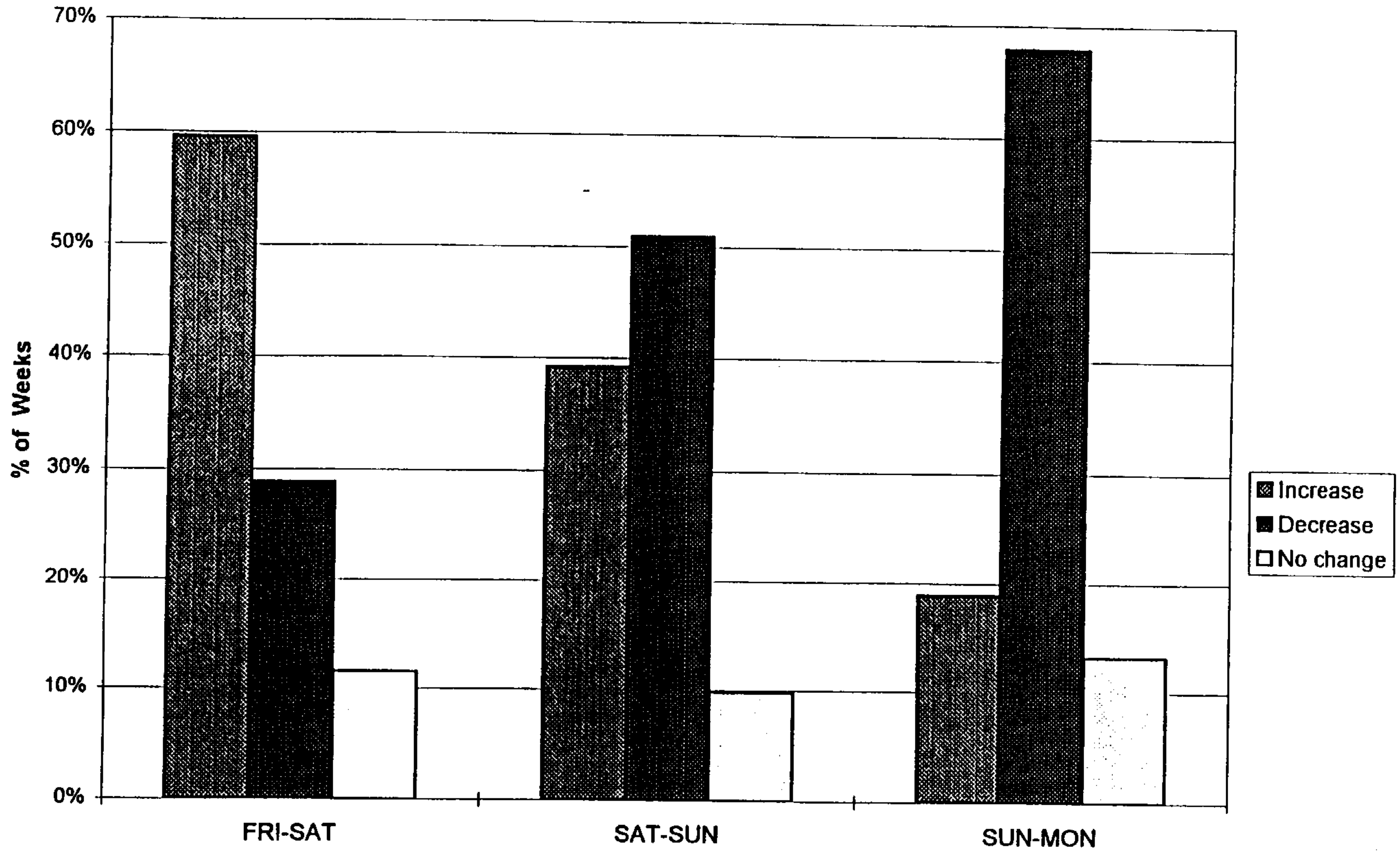

Figure 4-6. Basinwide Friday-Monday differences in peak ambient ozone levels for the 1994-95 smog seasons.

HC data is only available for this three-month period). Basinwide concentrations of both NO_x and NMHC decreased approximately 20% in 1996 over 1995.

Table 4-17shows the four-day differences in maximum ozone concentration for 1996 as a percentage of the number of weekly changes (increases, decreases, and no change) over the smog season. For 69% of smog season weeks in 1996 the Basin ozone concentration increased from Friday to Saturday, compared to 60% in 1994-95 (Table 4-17). The percentage of weeks with increases in ozone from Saturday to Sunday ranged from 46% to 60% in the subregions evaluated. The San Gabriel Valley subregion experienced more pronounced ozone changes as a result of ozone-precursor differences during the 48-hour weekend period, in particular, 21 out of 26 (81%) Saturdays experienced higher average peak ozone than Fridays.

Table 4-16. Changes in ambient levels of ozone-precursors (0600-0900 PDT) from 1994-95 to 1996 (July-September)

NOX (pphm)	1994-95	1996	Differences	%Change	%Change Over 3 Years
Basin	9.7	7.3	-2.4	-25%	-28%
Coastal/Metropolitan	10.1	8.4	-1.7	-17%	-18%
San Gabriel Valley	9.7	8.5	-1.2	-12%	-13%
Inland Valley	10.8	9.1	-1.7	-16%	-17%
NO2 (pphm)	1994-95	1996	Differences	%Change	%Change Over 3 Years
Basin	4.2	3	-1.2	-29%	-33%
Coastal/Metropolitan	3.9	3.1	-0.8	-21%	-23%
San Gabriel Valley	4.5	3.6	-0.9	-20%	-22%
Inland Valley	5	3.9	-1.1	-22%	-25%
NO (pphm)	1994-95	1996	Differences	%Change	%Change Over 3 Years
Basin	5.5	4.3	-1.2	-22%	-24%
Coastal/Metropolitan	6.1	5.3	-0.8	-13%	-14%
San Gabriel Valley	5.2	4.9	-0.3	-6%	-6%
Inland Valley	5.9	5.2	-0.7	-12%	-13%
NMHC (ppbC)	1995	1996	Differences	%Change	%Change Over 3 Years
Los Angeles North M	675	548	-127	-19%	-21%
Burbank	758	553	-205	-27%	-31%
Azusa	560	522	-38	-7%	-7%
	Average NMHC			**-18%**	**-20%**

Table 4-17. Overview of day-of-the-week peak ozone differences for the 1996 smog season (May-October).

Basinwide	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	69%	54%	12%
% of weeks w/decreases	19%	46%	76%
% of weeks w/no change	12%	0%	12%
Coastal/Metropolitan Sites	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	58%	56%	12%
% of weeks w/decreases	27%	36%	62%
% of weeks w/no change	15%	8%	26%
San Gabriel Valley Sites	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	81%	60%	4%
% of weeks w/decreases	15%	40%	81%
% of weeks w/no change	4%	0%	15%
Inland Valley Sites	FRI-SAT	SAT-SUN	SUN-MON
% of weeks w/increases	77%	48%	15%
% of weeks w/decreases	19%	36%	81%
% of weeks w/no change	4%	16%	4%